


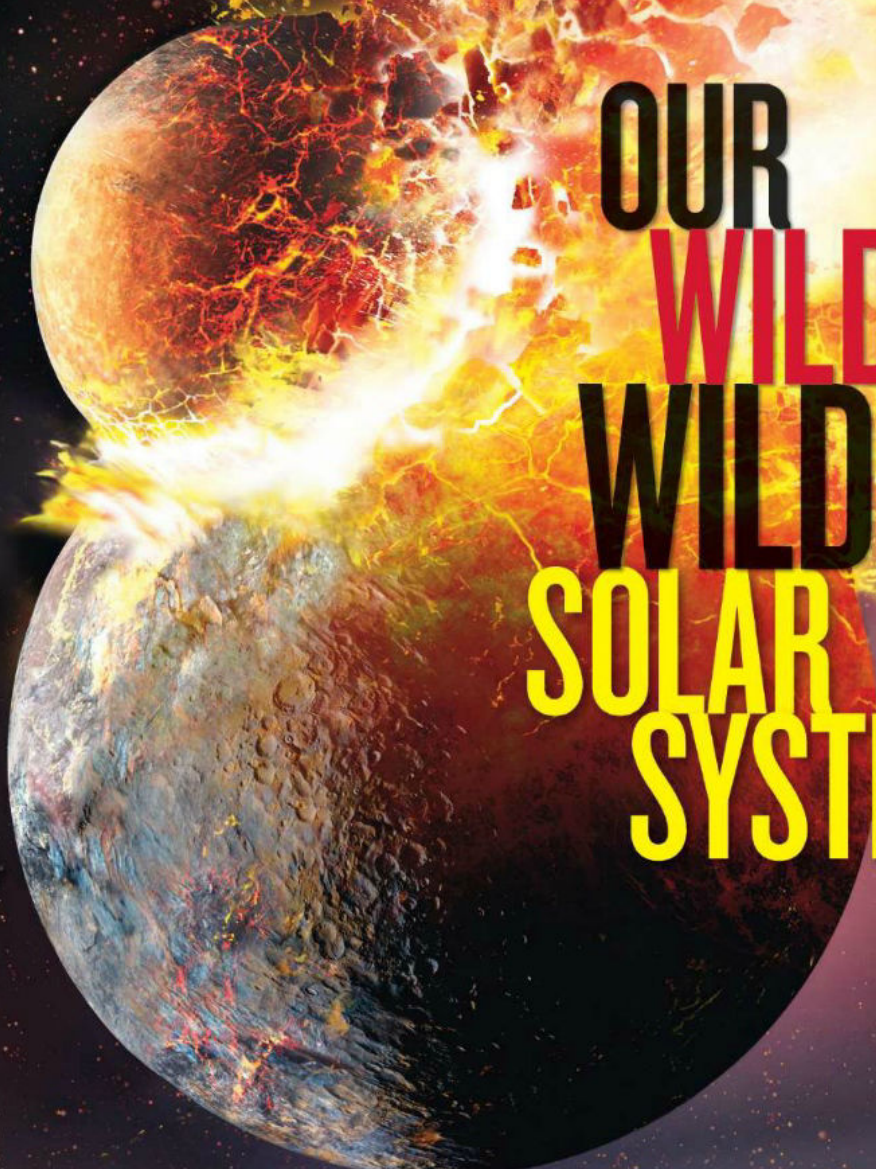
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SONGBIRDS: THE MOST DANGEROUS JOURNEY

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NATIONAL GEOGRAPHIC



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Galapagos Fur Seal (*Arctocephalus galapagoensis*)

Size: Head and body length, 1.1 - 1.6 m (43.3 - 63 inches) **Weight:** 28 - 68 kg (61.7 - 149.9 lbs)

Habitat: Breeds exclusively on the Galapagos archipelago **Surviving number:** Estimated at 10,000 - 15,000



Photographed by Michael S. Nolan

WILDLIFE AS CANON SEES IT

The best never rest. That's the philosophy the dominant male Galapagos fur seal lives by, defending his rule over a territory nonstop for four to six weeks until he becomes exhausted or is ousted by another male. The female takes charge of caring for their young, spending the first week of its life with their pup, then returning to it every other day after foraging. Slipping into the water in the darkness, fur seals search out small squid and

fish that migrate to the ocean surface at night. Highly dependent on food availability, they are vulnerable to devastating mortality rates when food sources disappear due to El Niño weather events.

As we see it, we can help make the world a better place. Raising awareness of endangered species is just one of the ways we at Canon are taking action—for the good of the planet we call home. Visit canon.com/environment to learn more.

*There wasn't much more
than one bite of meat on the
two birds put together.*

page 88



LUCIANO CANDISANI

126

This baby yacare caiman is just a bit longer than a pencil. In adulthood the South American crocodilian can reach eight feet in length and is a fearsome predator.

July 2013

28 **Mars Gets Its Close-Up**

The rover Curiosity is taking red planet portraits.

By John Grotzinger

42 **It All Began in Chaos**

The giant planets didn't always sit where they are today. Our solar system was shaped by a wild and stormy youth.

*By Robert Irion Photographs by Mark Thiessen
Art by Dana Berry*

60 **Last Song for Migrating Birds**

Across the Mediterranean millions are killed for food, profit, and cruel amusement.

By Jonathan Franzen Photographs by David Guttenfelder

90 **Our Missing Ancestor**

Meet a mysterious member of the human family.

By Jamie Shreeve Photographs by Robert Clark

102 **Genes Are Us**

Humans share a quarter of their genes with a grain of rice—a sign of our common heritage.

104 **Daniel Kish: Bat Man**

Blind since 13 months, he explores the world—and even rides a bike—by clicking his tongue.

By Michael Finkel Photograph by Marco Grob

106 **Hay Beautiful**

A walk through the grass-growing meadows of Transylvania will cheer your spirits. The old art of making hay is the reason.

By Adam Nicolson Photographs by Rena Effendi

126 **The Comeback Croc**

Thirty years ago the yacare caiman seemed doomed to a leathery death. What happened?

By Roff Smith Photographs by Luciano Candisani

- 4 [Editor's Note](#)
- 6 [Letters](#)
- 8 [Survival Guide](#)



10 [VISIONS](#) ▶

16 [Your Shot](#)

19 [NEXT](#)

[Dr. Porcupine](#)

Needles are being redesigned to resemble a porcupine's quill.

[Firsts and Lasts](#) ▶

Our quiz tests your knowledge of exploration milestones.

[Burl Snatchers](#)

A burl is a lumpy growth on a tree trunk. Thieves crave them.

[Peruvian Priestess](#)

Archaeological finds attest to the power of women.

[Stormy Forecast](#)

Has climate change affected the intensity of hurricanes?

[The Final Rabbs' Frog](#) ▶

Toughie, a fringe-limbed tree frog, is the last of his kind.



- 136 [NG Connect](#)
- 138 [The Moment](#)
- [Flashback](#)



On the Cover This illustration shows how the moon was likely born. A Mars-size protoplanet crashed into Earth billions of years ago. Rocky debris spun into space and formed our satellite within a century.
Art by Dana Berry

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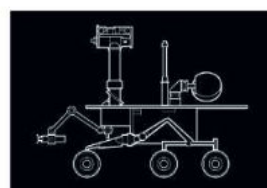
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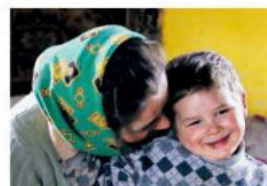
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The photographer tells how the story affected him.



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FROM TOP: MATTHEW TWOMBLY, NGM STAFF; DAVID GUTTENFELDER; RENA EFFENDI

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There is another predator: man.

An adult European bee-eater (*Merops apiaster*) soars over Lesbos, Greece.

A Flying Shame

The European bee-eater is nature at her gaudy best. It's a tiny bird, with a scimitar beak and feathers the colors of a crazy quilt: saffron throat, turquoise breast, chestnut crown. I first really spent time watching bee-eaters while on a boat on the Zambezi River. The birds had dug nests into the sandy banks along the river. They were darting around, chasing dragonflies to feed their chicks, iridescent in the sunlight.

Most bee-eaters run a gantlet to get to Africa, having flown—as they do every year—from southern Europe, across the Mediterranean, over the Sahara, and finally to southern Africa. Many don't survive the trip. The stress of migration claims some, raptors get others. But there is another predator: man.

"Last Song," this month's story reported by

Jonathan Franzen and photographed by David Guttenfelder, is about human carelessness and a lack of regard for these beautiful creatures. Each year, from one end of the Mediterranean to the other, hundreds of millions of migratory birds such as the bee-eater are killed by hunters. They use guns, nets made of ultrafine nylon, and sap-coated traps. Killing these birds has nothing to do with feeding a population. It is callous and indiscriminate slaughter. The orioles, warblers, and shrikes Franzen writes about—like the mockingbird in Harper Lee's novel—"don't eat up people's gardens, don't nest in corncribs, they don't do one thing but sing their hearts out for us."

A handwritten signature in black ink, which appears to read "Jonathan Franzen".

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New Oil Landscape

When Edwin Drake made his first well in 1859, he could be forgiven the waste of his first gusher. He didn't know what was going to happen. The second well taught us that this phenomenon might be repeated. By the third well the oil industry should have been prepared to catch this early petroleum spurt so it wouldn't be wasted. Here we are 150 years later still performing the same stupidity on an almost ceremonial level. Idiots stand around getting drenched with oil in puddles of polluting petroleum. Arguably, a home could be heated for years with the waste.

ROBERT W. POLLACK
Valhalla, New York

Do they truly believe they can play roulette with nature and win? Fatten the coffers now, because they will be needed to pay for the cleanup.

ELISABETH SMITH
Omaha, Nebraska

Edwin Dobb's article, as well as Chris Johns's editorial about the Bakken oil play in North Dakota, reflects the dichotomy we face in western North Dakota: prosperity at a dear price. When any change comes to a region, there

are always fear and skepticism. We ponder whether the environment can sustain the physical disruption of the land, while we watch our small towns' infrastructures collapse under the weight of more and more people. It really is the best, and worst, of times for North Dakota.

JACKIE HOPE
Dickinson, North Dakota

The article was thrilling. We have the resources, technology, and drive to continue to be the

world's leader. If there are side effects from all of this, we will overcome them and thrive again.

DAN SHAUGHNESSY
Rockledge, Florida

I expected a negative portrayal of the oil industry and wasn't surprised. By my count you had 18 photos, graphics, and captions: 10 negative, 6 neutral, 2 positive. Your subtitle, "The Promise and Risk of Fracking," is at odds with the bias within.

JOHN RHODES
Dallas, Texas

Corrections

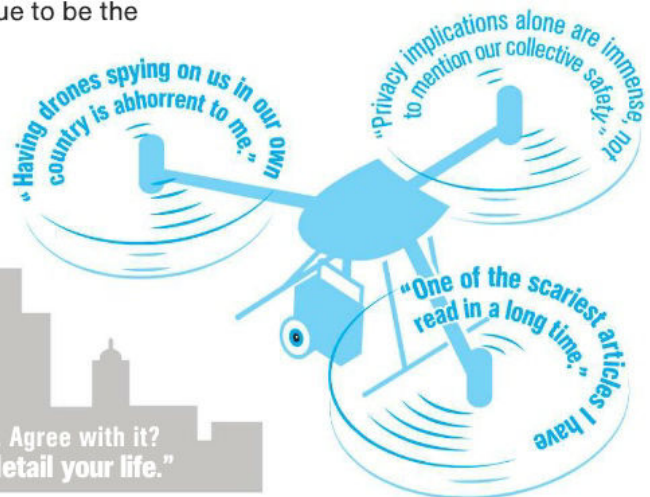
MARCH 2013, EXPLORERS QUIZ The correct medical symbol should have been the staff of Asclepius, which has one snake (or guinea worm) wrapped around a rod; we showed the caduceus, which has two intertwined snakes.

THE NEW OIL LANDSCAPE Page 44: A well south of Williston was described as having 25 legs, each of which was fracked separately. We should have stated that it has 25 stages.

RETURN TO RIVER TOWN Page 90: Chen Zhenyong should have been spelled Chen Zhengyong. Chen Hongli should have been spelled Chen Hongni.

THE DRONES COME HOME Page 134: The inset photo should have been credited to Julie A. Adams and Steven A. Wernke, Vanderbilt University.

FEEDBACK Readers responded to the idea that drones could watch them.



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Your story could have been an episode of *The Twilight Zone*: A culture, in an attempt to sustain its unsustainable lifestyle, destroys its own landscape in order to find every last drop of the poisonous fuel source.

PAUL WHEELER
Ottawa, Illinois

Oil company executives and their attorneys understand this about many hardworking, no-nonsense American workers: On one hand we'll condemn a man for squandering his paycheck on a night of whiskey and gambling. On the other we'll jump at the chance to get in on a fly-by-night, get-rich-quick binge like fracking that will generate a short-term money boom out of long-term toxification of local soil and aquifers. Most won't notice the similarity, and those who do won't find it difficult to

The idea that some kid can now play video games in my airspace is a very scary thought.

rationalize. To someone like Susan Connell, making \$2,000 instead of \$600 by the end of the week can only look like a good thing. In the face of that kind of temptation, one's concern for the future health of the land and community is understandably distorted or obscured. The oil industry, as ever, is counting on it.

CARL KISTLER
Glenside, Pennsylvania

Drones

I believe that in the wrong hands or even the right hands—and one doesn't have to go far to find either—the use of drones can become another tool to be used against the enemy, perceived or otherwise. Maybe soon everyone will be able to spy on each other—and ultimately hurt others—if civilians, police, and anyone with the ready cash can have them. So much for peace. Reminds me of *Mad* magazine's "Spy vs. Spy."

DONNA MARQUART
Ripon, Wisconsin

Drones are just another reason for people around the world to despise Americans. We are the "wizard," and when you look behind the curtain, there is a 120-pound, zit-faced boy playing video games with people's lives. The idea that some kid can now play video games in my airspace is a very scary thought.

KYLE EDWARD SIMMS
Tokyo, Japan

I can fully understand the military having these drones, but 18,000 police forces? I know they say that they will be used for rescues and crime scene reconstruction, but we all know what is really coming. This will be an infringement on your Fourth Amendment rights, and now it is easier to understand why your forefathers put in the Second Amendment. I think these things will be dropping from the skies like ducks in a duck hunt.

BOB HEARD
Port Colborne, Ontario

Have none of the leaders in our government, military, or scientific community who are pushing development and deployment of these devices read or watched any of the cautionary tales about humans farming out the dirty work of war and killing to machines? *Colossus: The Forbin Project* and *The Terminator* are just two that come to mind.

FRANK POMATA
Patchogue, New York

Night Gardens

In all fairness to Louis XIV, Nicolas Fouquet was Louis's finance minister who embezzled a fortune from the French government, built an extravagant palace for himself, and threw an elaborate party to impress the king and nobility. The king was correct to confiscate the property and imprison him.

GARY MILLER
Davenport, Florida

SURVIVAL GUIDE

Sarah Parcak

I know how Sarah Parcak must have felt when she was stung by a scorpion. It happened to me in Belize. While sleeping, I felt like I'd been stabbed with an ice pick. My fingers, tongue, and mouth began to tingle. My heart was racing as I lay in bed. I remembered a doctor once told me if your condition does not get worse, it usually is not serious. The next day our guide said I had been stung by a nonlethal scorpion, and I would be back to normal in about 14 hours—which I was.

BILL RUZGIS
Long Beach, California



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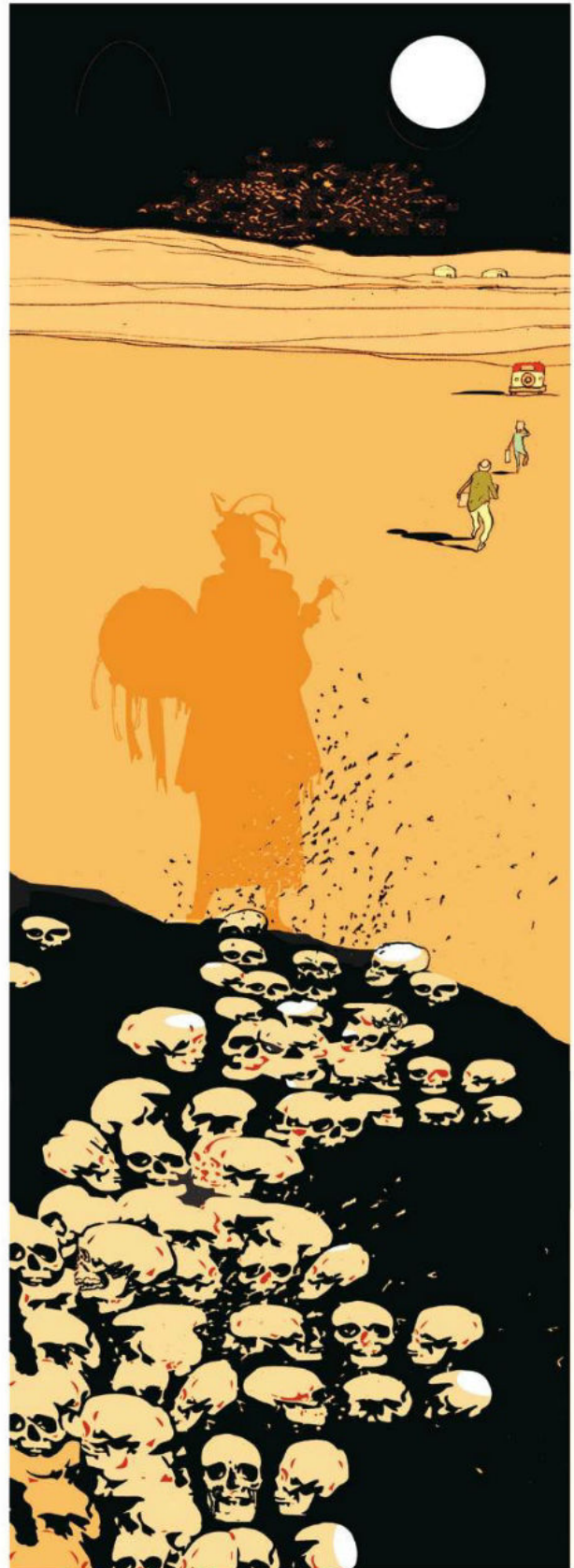
LOCATION
Mongolia

Grave Sights My team drove four days west from Ulaanbaatar toward the western border, near Kazakhstan, to work at an ancient burial site—almost a thousand miles through Mongolia's central steppes, the Gobi, and the Altay Mountains. When we stopped in a village to ask for directions, we were told the site was cursed. It was a cemetery for royals from the Xiongnu Empire. The Great Wall of China had been built to keep the Xiongnu out.

As we drove up to the site, we had a feeling something was wrong. It was eerily quiet. Usually after a day of excavation, everyone is sitting around a bonfire socializing. Not here. The site was in the middle of the desert, yet it was swarming with mosquitoes. Some of the local team had been bitten so many times their skin was infected from scratching.

Another team had excavated the site decades before and had left huge craters behind. Over the years people have been injured and livestock and wildlife killed by falling into them. As I stood on the edge of one of these deep pits, I felt anxious, like someone was watching us. It was as if the place were angry we were there. I told the dig team we could study the skeletons when they brought them to the museum in Ulaanbaatar. Then we left.

Most people are uncomfortable being surrounded by the dead. My father, a scientist, has expressed concern that ghosts from excavated skeletons may follow me around. My response to him is that I am not disturbing these skeletons but remembering the ones who have long been forgotten. Besides, I told him, if I ever felt the skeletons did not want me there, I would leave. This one time I did.



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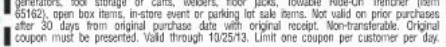


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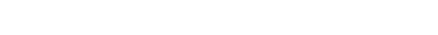
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VISIONS



Armenia

Beauty is in the beheld eye of a 16-year-old boy in Yerevan. In this highly magnified view of his iris's surface architecture, the central black pool is the pupil, and his lashes are reflected by the cornea. His eyelids appear as pink rims at top and bottom.

PHOTO: SUREN MANVELYAN







Iran

Visitors inspect a ruined dakhma, or tower of silence, near Yazd. In the Zoroastrian tradition, dead bodies—believed to be in danger of contamination—were left on these raised, circular structures, to be purified by vultures and the elements.

PHOTO: JUSTYNA MIELNIKIEWICZ



Germany

A color-enhanced electron microscope photo reveals a half-millimeter-long tardigrade in moss. Called water bears, these eight-legged, alien-looking invertebrates can survive extreme pressure, radiation, and temperatures—and years without food.

PHOTO: EYE OF SCIENCE/SCIENCE SOURCE

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EDITORS' CHOICE

Kyle Ueckermann
Oulu, Finland

Layers of ice had grown on windows in Molkoköngäs, where Ueckermann and his wife, Tiialotta, stopped during a midwinter road trip. While exploring an abandoned cabin, he saw her image through a window, distorted by the ice.



READERS' CHOICE

Ance
Yogyakarta, Indonesia

To build the scene for this photo, Ance created a small puddle of water, then placed an ant atop a pile of moss that he had found in his yard. As the ant started moving, Ance, a macrophotographer, captured the moment right before it jumped from the moss.

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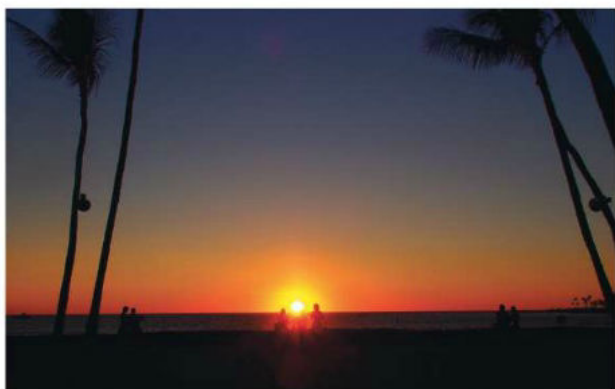
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VISIONS | YOUR SHOT



Tatyana Druz Hadera, Israel

At a cat exhibition near her hometown, Druz took portraits of many of the animals. One sphynx—a breed with very little hair—was more curious than others that day, coming so close that it almost touched Druz's lens.



Tim Grams Anchorage, Alaska

With some spare sheets of clear plastic he had around the house, Grams built a four-foot-tall frame to photograph redpolls that spend the winter in Alaska. He sprinkled sunflower seeds to attract the birds, then set a remote release on his upward-pointing camera and went inside.



Hamed Tizrooyan Sari, Iran

On a tour of Iran's Touran National Park, Tizrooyan was looking specifically to photograph an onager, a relative of the horse. After several hours he came across a pack of them. Standing about 250 feet away, Tizrooyan snapped his shutter the moment they made eye contact.



Geb Bunado

Limay, Philippines

At the Philippines' Sinulog festival, which honors Jesus as a child, women participated in a street dance competition. Drawn to the colorful skirts, Bunado positioned his camera at waist level, hoping to capture the motion as the women danced.

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GO BEHIND THE LINES WITH
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BATTLEGROUND AFGHANISTAN

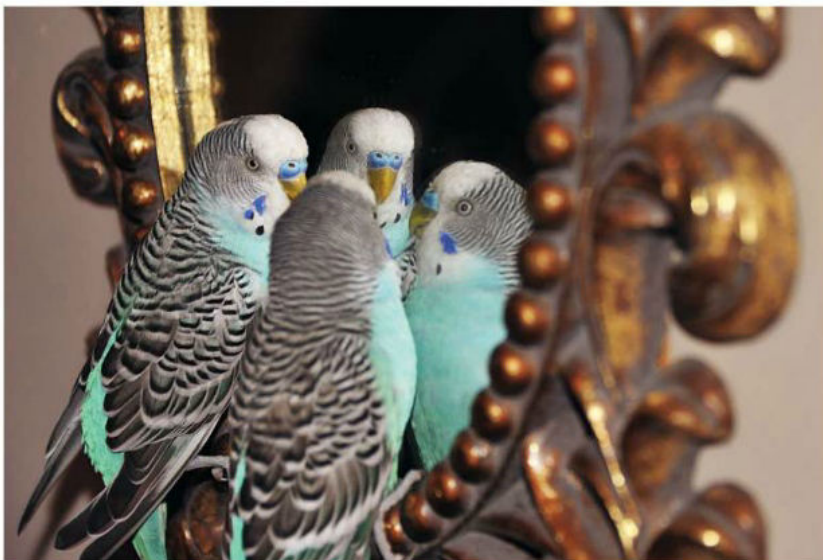
NEW SERIES
COMING IN JULY





Jun Su Brooklyn, New York

Wanting to show visiting friends the character of New York, Su took them to Battery Park, where unabashed squirrels interact with people for food. With a container of almonds, this young woman kept a squirrel on her head for ten minutes, Su says, while a small crowd took photos.



Hsingwei Lee

Vienna, Virginia

When Lee's daughter let the family's two parakeets out of their cage, they both flew quickly to a nearby mirror. "You could see their amazement at what they were seeing," Lee says. Seconds after he snapped this shot, the birds flew to another part of the house.

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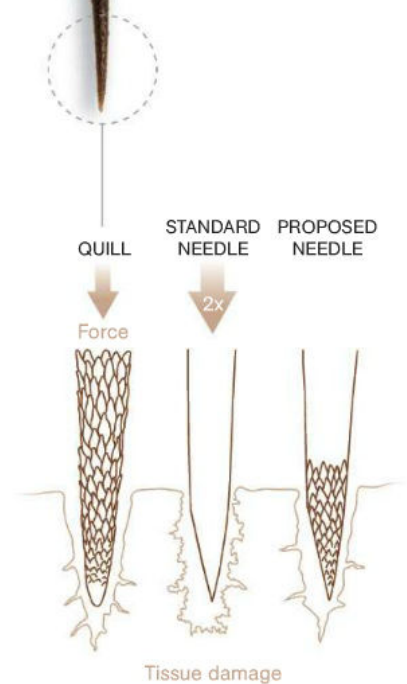
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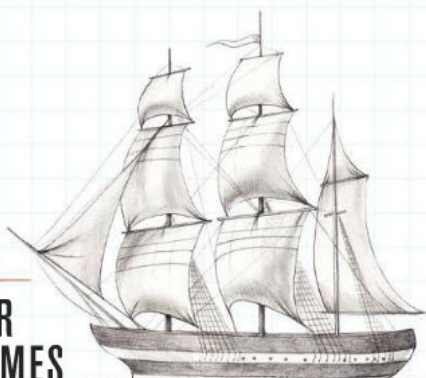
NEXT



Quill Power North American porcupine quills are clingy types—once one is lodged in flesh, it takes twice the force of insertion to pull it out, because of a series of barbs along its tip. This discovery led a team of medical researchers to a pointed conversation: Why not replicate a quill's barbs to make drug-delivery and internal patches hold fast, even when wet?

Hypodermic needle architecture could also benefit. The less push needed to pierce flesh, the less chance of overshooting. Barbed quills take about half the pressure a needle does to insert, which may make synthetic versions better for procedures like spinal taps. To avoid tearing tissue on removal, Harvard's Jeffrey Karp and MIT's Robert Langer are testing timed degradability, so barbs lose grip. In some cases, a difficult-to-remove needle might be useful too, including for immunizing cattle and performing battlefield medicine. —*Johnna Rizzo*





1. SIR JAMES

CLARK ROSS COMMANDED ONE OF THE LAST GREAT VOYAGES OF EXPLORATION MADE ENTIRELY UNDER SAIL. WHERE DID HE GO? A. The Siberian Shelf B. The Ryukyu Trench C. The coast of Antarctica D. Komodo Island

2. WHAT MID-20TH-CENTURY EVENT WAS THE FIRST STEP IN A MAJOR NEW FIELD OF EXPLORATION AND ALSO GAVE US A NEW TERM FOR THE HIPSTERS

OF THE DAY? A. The flight of PS-1 B. The first dive into the Mariana Trench C. Thor Heyerdahl's Pacific voyage on the balsa raft *Kon-Tiki* D. The discovery of the lost city of Ubar in Oman

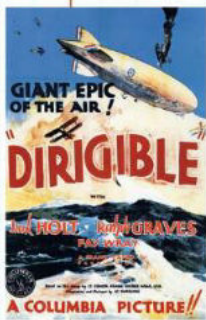
3. CAL RODGERS'S EXPEDITIONARY

FORCE INCLUDED HIS WIFE, HIS MOTHER, A MAID, A CHAUFFEUR, THREE MECHANICS, AND A DOZEN MARKETING MEN. WHAT CHALLENGE DID RODGERS SET OUT TO CONQUER? A. First automobile crossing of the Sahara B. First bicycle trip the length of South America C. First flight across the United States D. First transatlantic swim

4. "I AM JUST GOING OUTSIDE AND MAY BE SOME TIME."

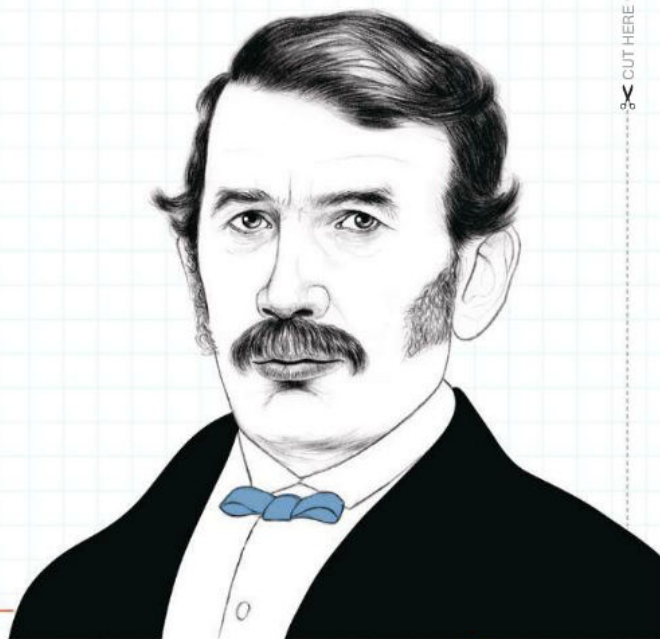
THOSE INNOCUOUS-SEEMING LAST WORDS SAID TO HAVE BEEN UTTERED BY AN EXPLORER HAVE LIVED ON AND BEEN ECHOED IN A FRANK CAPRA MOVIE, A TOM STOPPARD PLAY, AND THE FICTION OF TERRY PRATCHETT.

WHO SPOKE THEM? A. Mungo Park, before his drowning in Nigeria B. Lawrence Oates, stepping from his tent into an Antarctic blizzard C. Percy Fawcett, heading into the Brazilian rain forest D. Juan Ponce de León, before being struck by an arrow in Florida



FIRSTS AND LASTS

Everybody remembers who was first to walk on the moon (Neil Armstrong), not so many who was last (Eugene Cernan). That's how it goes in the history of exploration. But last things also have their fascination, and they often entail just as much courage and sacrifice. This quiz looks at both sides of the equation, some famous—and not so famous—firsts and lasts.



5. DAVID LIVINGSTONE,

THE GREAT 19TH-CENTURY EXPLORER, MISSIONARY, AND ANTISLAVERY ACTIVIST IN AFRICA, WAS HONORED WITH A FINAL RESTING PLACE IN LONDON'S WESTMINSTER ABBEY. BUT WHERE IS HIS HEART? A. Buried in his beloved Blantyre, Scotland B. Cut out and burned by his enemies C. In present-day Zambia D. Preserved in the collection of the Royal College of Surgeons

FIND ANSWERS ON PAGE 27.

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A monument to toughness. The people of Rhodes were ready for Demetrius and repelled his attack. To celebrate, they built the Colossus of Rhodes, a 107-foot bronze and iron giant that towered over the harbor like a ten-story trophy. It warned future invaders that "Rhodes is tougher than you think." You give the same message when you wear the Stauer *Colossus*.

The timepiece that works twice as hard. The *Colossus Hybrid Chronograph* will keep you on schedule, but it's about much more than time. The imposing case features a rotating gunmetal bezel that frames the silver, black and yellow face. You'll find a battalion of digital displays on the dial arranged behind a pair of luminescent hands and a bold yellow second hand. Powered by a precise quartz movement, the watch is doubly accurate in analog and digital mode.

The *Colossus* is packed with plenty of handy extras including a bright green EL back-light for enhanced nighttime visibility, a tachymeter along the outer dial and a full complement of alarms and split-second countdown timers. It secures with a folded steel bracelet that highlights a row of striking dark center links. It's a rugged watch that's more than ready for your daily grind.

More watch for less money. Big-name watchmakers raise their prices because they can get away with it. But Stauer wants to turn luxury on its head. We sent the *Colossus Hybrid* to an independent appraiser who works with auction houses, luxury estate sales and insurance companies. He valued the watch at \$199.* We thanked him for his professional opinion and then ignored it. Because we still want you to wear it for **ONLY \$49**.

Your satisfaction is guaranteed. Wear the Stauer *Colossus Hybrid Chronograph* for 30 days and if you are not 100% thrilled with your purchase, return it for a full refund of your purchase price. But once you get a taste of more watch for less money, it's likely you'll be back for more... and we'll be waiting.

WATCH SPECS: -Easy-to-read analog/digital modes -Back-lighting and luminescent hands -Tachymeter, countdown timers and alarms -Folded stainless steel bracelet fits a 6 3/4"-9" wrist

Colossus Hybrid Digital/Analog Watch

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A Knock on Wood Boston, Massachusetts, had a knotty problem in 2012: Public-park tree burls were being sawed off and carted away. Injury or illness causes the lumpy, oversize scars on tree trunks. Inside, intricately swirled grain is created as the tree heals, making them highly valuable for woodworking.

Hacking off burls doesn't immediately kill a tree but does shorten its life. "Trees don't heal like you and I heal. They callus over the wound but continue to rot inside," says Boston arborist Greg Mosman. A census of city trees estimated \$100,000 in damage. In California—where the market for burls is thriving—trimming burls from public redwood trees is a criminal offense. Boston didn't have a precedent, so police listed the arborist as the victim of destruction of property, and he went to court to recoup the losses to replant. —*Johnna Rizzo*

Selling burls can be big business when done legally (as above); they fetch \$75 to \$300 a pound from furniture designers and wood artists.



Status Symbol Power wasn't limited to men in the Lambayeque culture (A.D. 850 to 1250). The lavish burial site of a priestess found in northwestern Peru offers new insight into that culture's gender roles. Buried beneath a palace's ceremonial plaza at Chornancap, near the coast, the woman clearly had wealth and influence—her grave goods included this golden scepter (left). She likely performed rituals, received offerings, and celebrated the seasons, the phases of the moon, and the changing tides. —*A. R. Williams*

Meet the Beauty in the Beast

Discover this spectacular 6½-carat green treasure from Mount St. Helens!

For almost a hundred years it lay dormant. Silently building strength. At 10,000 feet high, it was truly a sleeping giant. Until May 18, 1980, when the beast awoke with violent force and revealed its greatest secret. Mount St. Helens erupted, sending up a 80,000-foot column of ash and smoke. From that chaos, something beautiful emerged... our spectacular *Helenite Necklace*.

EXCLUSIVE FREE
Helenite Earrings
 -a \$129 value-
 with purchase of
 Helenite Necklace



sits quiet, but this unique piece of American natural history continues to erupt with gorgeous green fire.

Your satisfaction is guaranteed. Bring home the *Helenite Necklace* and see for yourself. If you are not completely blown away by the rare beauty of this exceptional stone, simply return the necklace within 30 days for a full refund of your purchase price.

JEWELRY SPECS:

- 6 ½ ctw Helenite in gold-finished sterling silver setting
- 18" gold-finished sterling silver chain

Limited to the first 2200 orders from this ad only

Helenite Necklace (6 ½ ctw).....Only **\$149** +S&P

Helenite Stud Earrings (1 ctw)**\$129** +S&P

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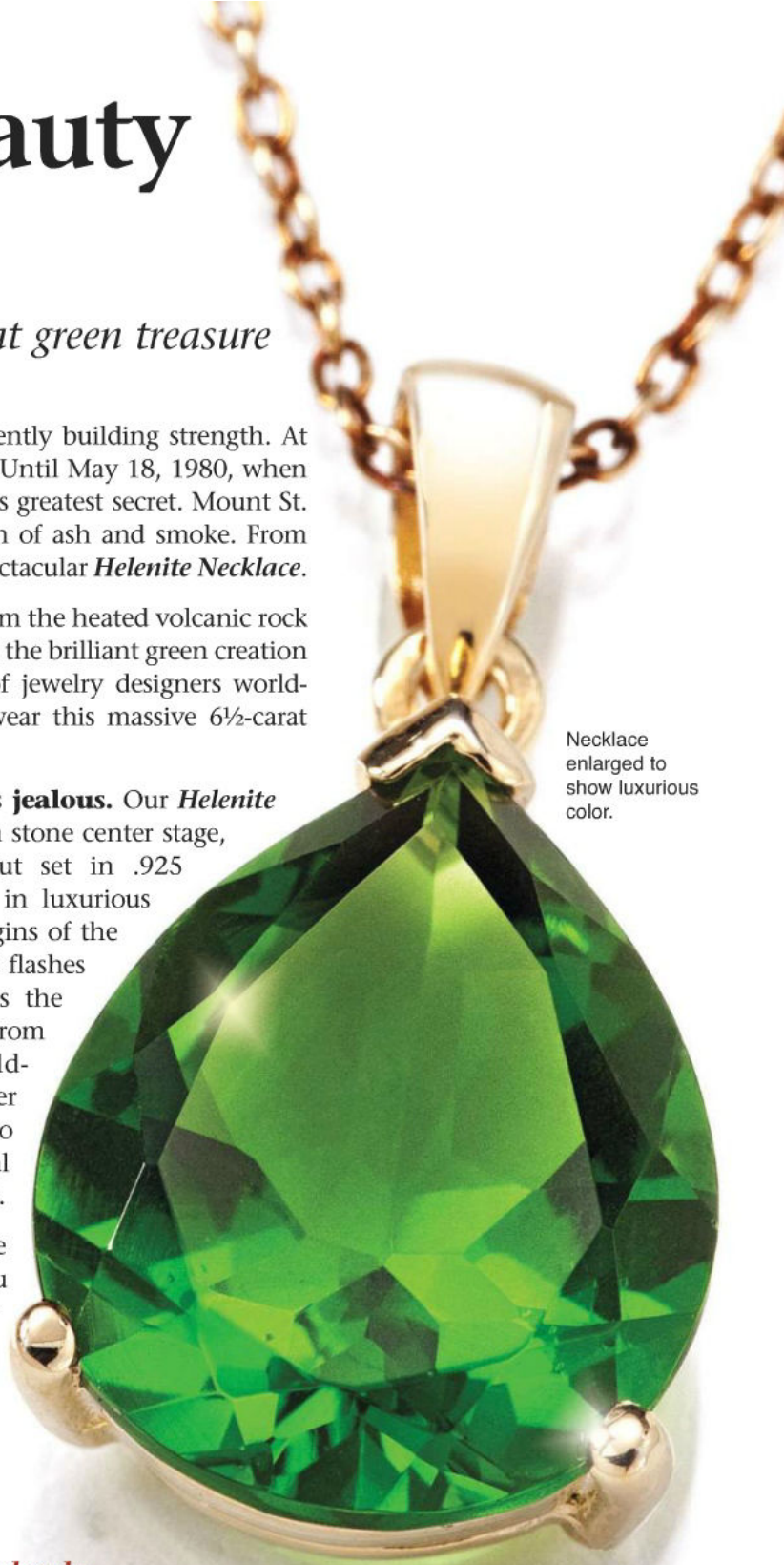


Rating of **A+**

Stauer® 14101 Southcross Drive W., Dept. HEL419-04,
 Burnsville, Minnesota 55337 www.stauer.com

Helenite is produced from the heated volcanic rock of Mount St. Helens and the brilliant green creation has captured the eye of jewelry designers worldwide. Today you can wear this massive 6½-carat stunner for *only \$149!*

Make your emeralds jealous. Our *Helenite Necklace* puts the green stone center stage, with a faceted pear-cut set in .925 sterling silver finished in luxurious gold. The explosive origins of the stone are echoed in the flashes of light that radiate as the piece swings gracefully from its 18" luxurious gold-finished sterling silver chain. Today the volcano



Necklace enlarged to show luxurious color.

"My wife received more compliments on this stone on the first day she wore it than any other piece of jewelry I've ever given her."

- J. from Orlando, FL
Stauer Client



Scan to view the gorgeous Helenite Necklace in all its radiant beauty.

NEXT

This map shows the seasonal intensity of hurricanes, typhoons, and tropical cyclones—all three names refer to the same phenomenon—since 1851 as recorded in NOAA's public archives. Storms in the Atlantic have been recorded for a much longer period, and therefore appear denser. Only in recent decades has activity in the more tumultuous Pacific been reliably monitored.

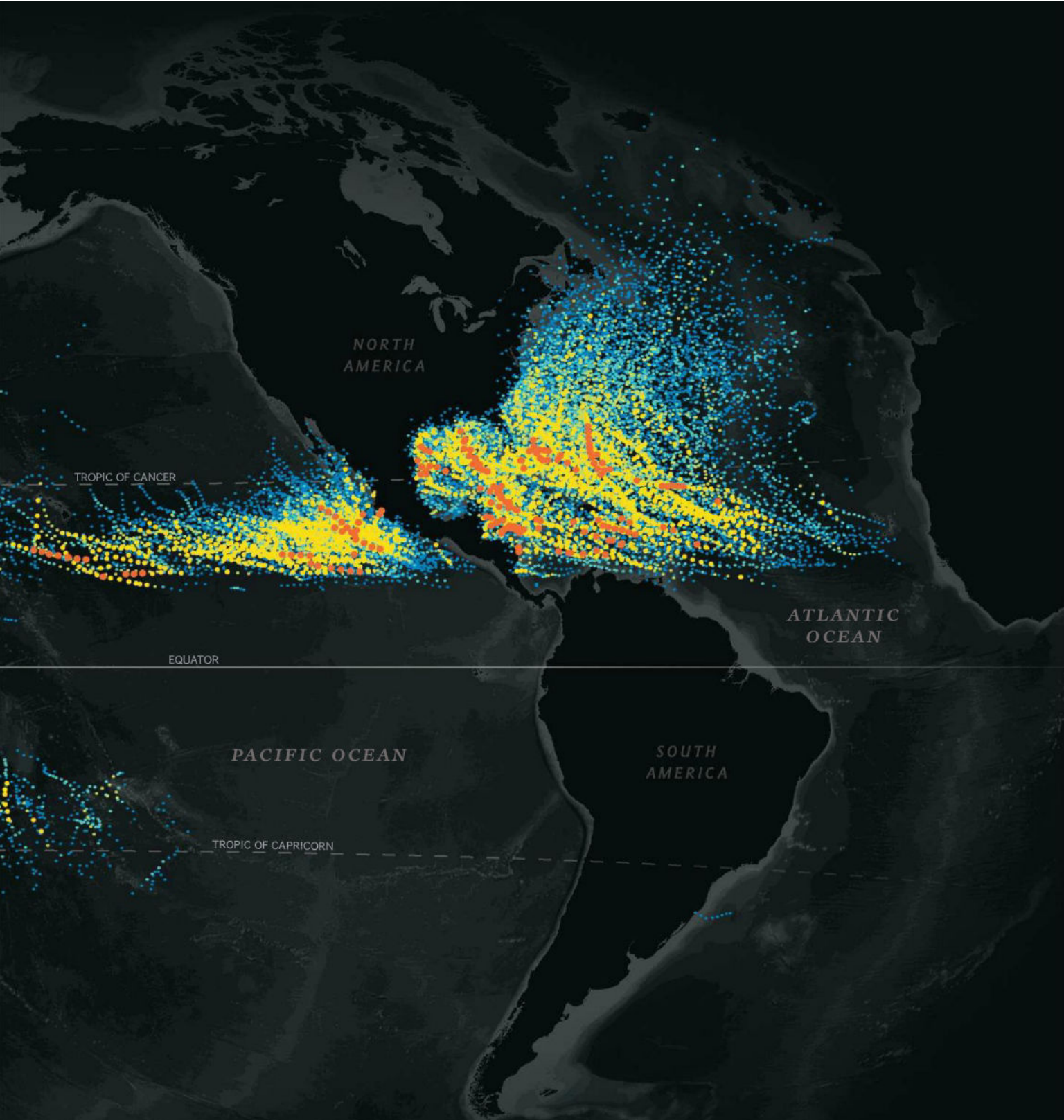
Hurricane detection over time by Saffir-Simpson scale

- Category 5
- Category 4
- Category 3
- Category 2
- Category 1

Stormy History Determining climate change's effects on hurricanes is a messy business. Globally, hurricane frequency doesn't seem to be increasing, but the proportion of strongest storms is, according to senior research scientist Greg Holland of the National Center for Atmospheric Research. The North Atlantic region has seen increases in hurricane frequency and intensity since the 1970s, says atmospheric scientist Jim Kossin of the National Climatic Data Center. Human influences on climate are difficult to detect in historical data sets of hurricane activity due to natural variability and incomplete records. Before airplanes and satellites, people conveyed information about hurricanes using two-way radios, firsthand accounts, and the telegraph. —Jane J. Lee

This chart shows summaries of historical hurricane seasons, adding up recorded length in days of each storm and where storms rate on the Saffir-Simpson scale throughout their lifetimes, for a sense of overall activity.





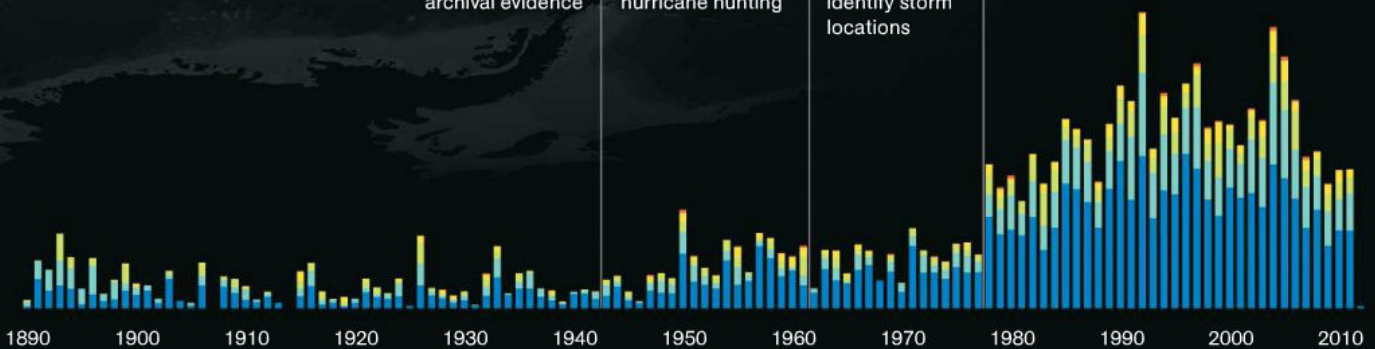
IMPROVEMENTS IN DETECTION

Historical best guesses, based on physical and archival evidence

Increased oceanic air travel and overt aerial hurricane hunting

Emergence of polar satellite tracking to identify storm locations

Storm detection and tracking increase dramatically with emergence of geostationary satellites

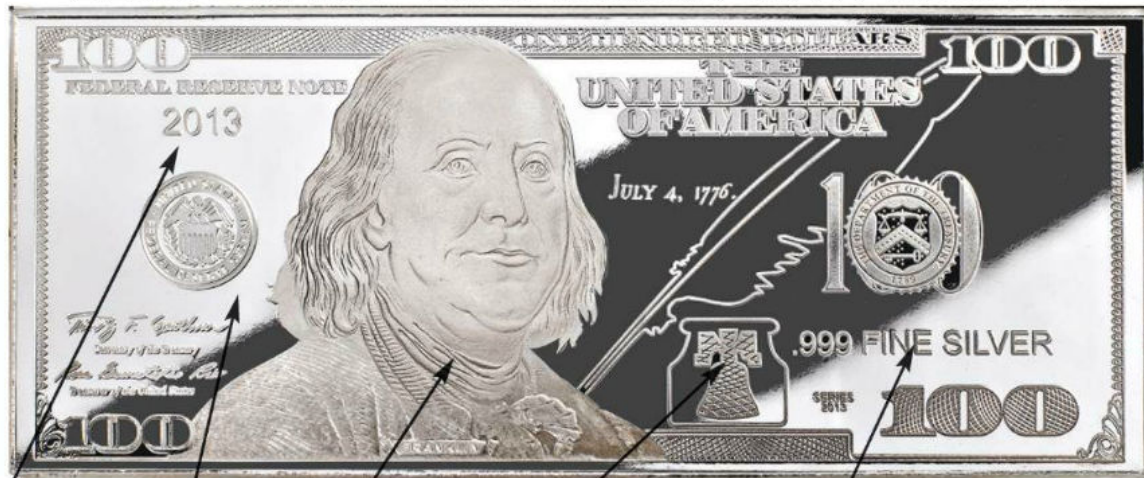


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WORLD'S FIRST

The 2013 \$100 SILVER PROOF

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AT \$99



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background

Larger Franklin
portrait

Liberty Bell, quill pen
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of pure silver bullion

Actual size is 6" x 2 1/2"

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This extraordinary piece of pure silver bullion has a surface area that exceeds 15 square inches...and it contains one Troy ounce of pure silver bullion!

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Down to One In 2005 researchers traveled to Panama on a rescue mission. The invasive chytrid fungus had been found in the country's mountains, threatening to eliminate entire populations of amphibians. Biologists loaded hundreds of frogs into crates, including several dozen rare Rabbs' fringe-limbed tree frogs and tadpoles, to protect them in U.S. labs.

Now only one Rabbs' remains. The others died of natural causes, and new tadpoles were never able to fully metamorphose in the labs. The last Rabbs'—nicknamed Toughie by his caretakers—lives inside a biosecure shipping container with several other rare frog species. Roughly the size of an adult's hand, he's fed a diet of crickets and is weighed weekly but otherwise touched sparingly. "It's pretty nerve-racking taking care of him," says the Atlanta Botanical Garden's Mark Mandica. Although Toughie is healthy, researchers believe he's also very old. —Daniel Stone

Rabbs' fringe-limbed tree frogs haven't been heard in the wild since 2007. The last known one (above) is at the Atlanta Botanical Garden.

ANSWERS FOR EXPLORERS QUIZ

- (C) Antarctica. Ross sailed from England in 1839, with H.M.S. *Erebus* and H.M.S. *Terror*, a pair of three-masted bomb vessels with reinforced hulls good for icy seas. The expedition discovered and mapped many notable features of the Antarctic coastline before sailing home in 1843—just as the era of oceangoing steamships was beginning.
- (A) PS-1. That's what Soviet technicians called the satellite they launched on October 4, 1957. Better known as Sputnik, it stirred up a worldwide sensation as humanity's first step beyond our own world. Several months later it also inspired *San Francisco Chronicle* columnist Herb Caen to dub members of that city's "beat" community "beatniks."
- (C) First flight across the U.S. Lured by a \$50,000 prize for flying coast-to-coast in fewer than 30 days, Rodgers lifted off from Brooklyn, New York, on September 17, 1911, in the *Vin Fiz Flyer*, a Wright Brothers biplane named for a popular soda brand. A train equipped with sleeping, dining, and hangar cars traveled with him. After numerous crashes, Rodgers arrived in Pasadena, California. He was the first person to cross the continent by air—but arrived 19 days too late to win the prize.
- (B) Lawrence Oates. Hobbled by frostbite, the 32-year-old explorer knew he was hindering the other survivors as they struggled back from their doomed 1911-12 expedition to the South Pole. With the nighttime temperatures at -40°F, Oates walked willingly to his death, not troubling to put on his boots. His companions pushed on but soon also died.
- (C) In present-day Zambia. Livingstone died from malaria and dysentery in May 1873 in the village of Ilala. Legend has it that before shipping his body home to Britain, his African followers attached a note to the corpse: "You can have his body, but his heart belongs in Africa!" They buried his heart near where he had died, and a cairn called the Livingstone Memorial now marks the spot.

THE NEW AGE OF  EXPLORATION

Field Trip on Mars

Curiosity, the Mars rover, is the next best thing to being there.





Powered by plutonium, NASA's one-ton, nine-foot-wide rover can cover a hundred yards in a day, rolling over large rocks on six aluminum wheels. Four cameras scan for treacherous ground ahead.

NASA/JPL/MALIN SPACE SCIENCE SYSTEMS (MSSS)



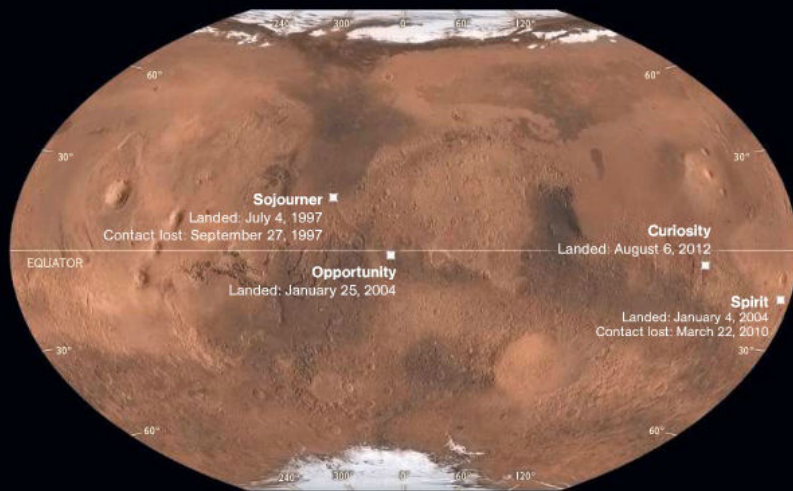
This is what you'd see from Curiosity's landing site. The rover made this panorama of Gale crater with a camera perched about six feet off the ground, like human eyes. At left and right are gray blast marks left by the sky crane's rockets as it landed the rover. In the distance lies three-mile-high Mount Sharp, where Curiosity is headed.

NASA/JPL/ASU



Watch a video from Curiosity's descent and learn more about the rovers on our digital editions.





Rovers on Mars

Curiosity is the latest and by far the largest of four NASA rovers. In 1997 Sojourner, the smallest and simplest, proved that Mars roving was possible. Spirit and Opportunity analyzed rocks, confirming evidence from orbiters that large amounts of water had once been present on Mars. (Opportunity is still roving after nine years and 22 miles.) Curiosity can drill into rocks and scoop the powder into an onboard chemical lab. It's looking not just for water but also for ancient environments where microbes could have lived.





Curiosity landed in what turned out to be an ancient streambed. Driving away, it descended into the small depression that lies just ahead and to the left, where it spent months drilling into its first rocks. They contained chemical evidence that the place had once been not only water covered but also habitable.

NASA/JPL/MSSS

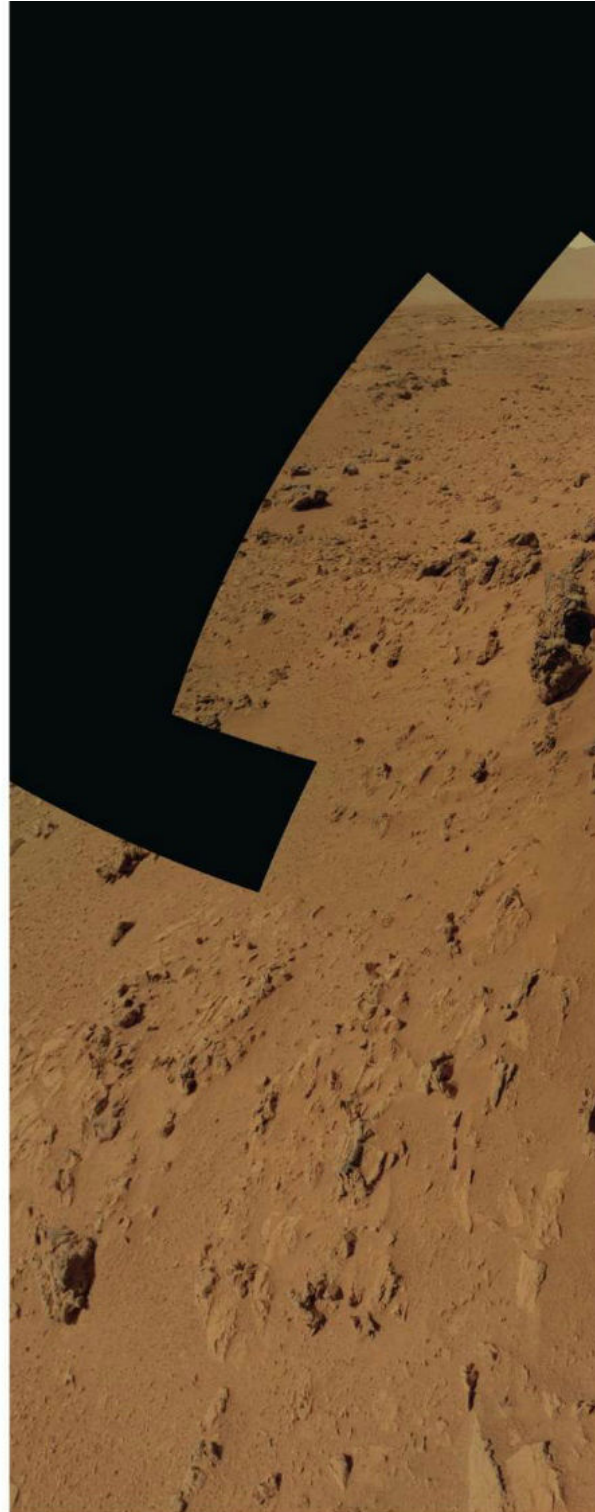
By John Grotzinger

“There is no foreign land; it is the traveller only that is foreign.”

—Robert Louis Stevenson

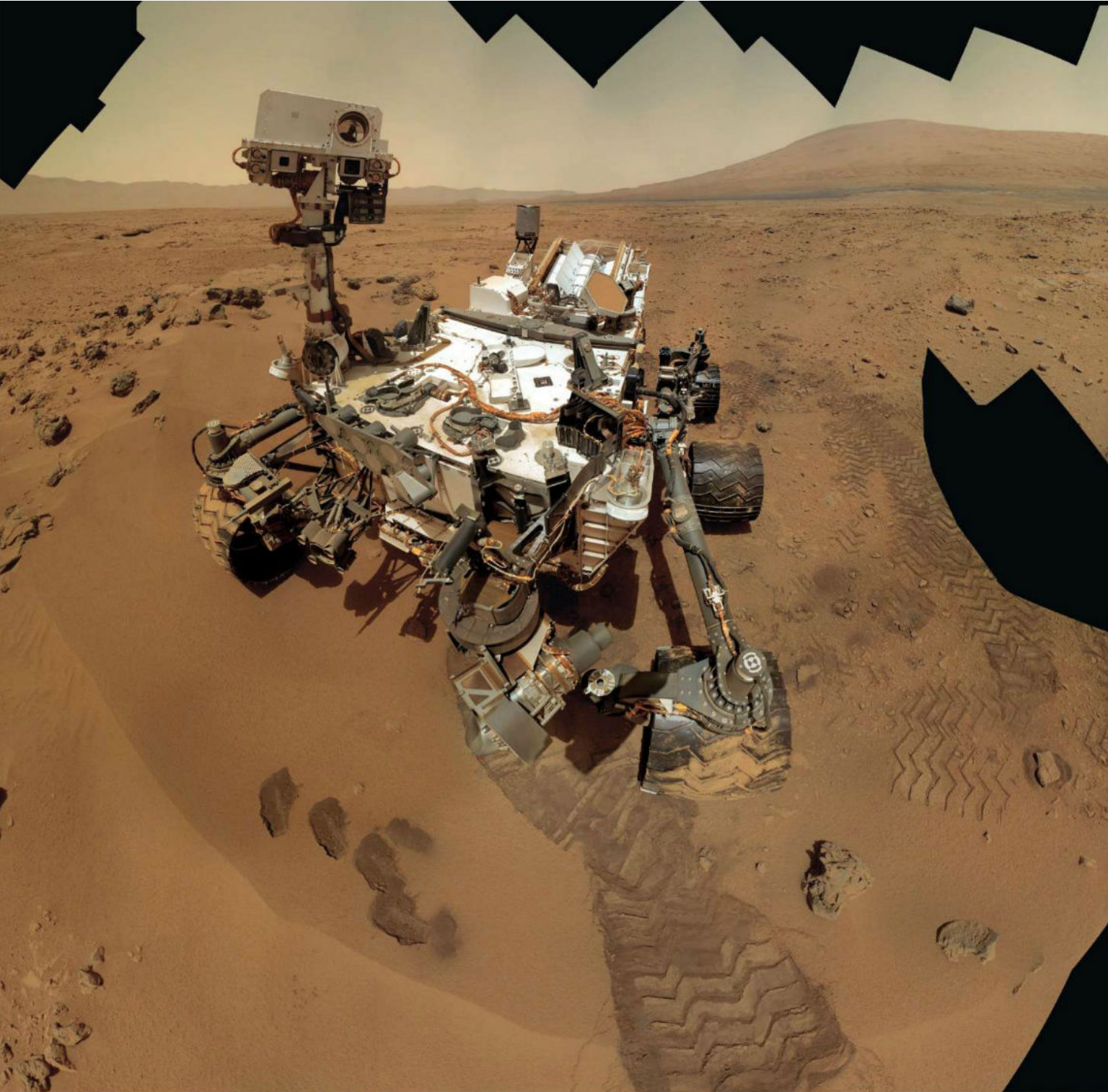
Stevenson, a Scot, was exploring California in 1880 with his new bride. I'm one of a team of more than 500 travelers exploring Mars from California with the most sophisticated robot ever sent to another planet. As I write, Curiosity is pounding a hole into a rock in Gale crater. That Neanderthal feat may not seem like proof of its sophistication. But it is. It took us ten years of engineering on Earth and six months of preparation on Mars to get to that rock. Drilling a two-inch-deep hole into it and extracting a baby-aspirin-size piece will take weeks more. We're doing it all to look for chemical evidence that Mars is not so different from Earth—that it too was once hospitable to life.

I'm a geologist, and I do fieldwork on Earth. I usually head out with only a handful of other people. We drive into remote areas with four-wheel-drive trucks or get dropped off by small airplanes or helicopters. Then we walk a lot. To plan a field campaign takes months, not a decade, and when I want to sample a rock, I reach into my rucksack, grab my rock hammer, and knock off a piece. Sampling takes minutes, not weeks. Back in the lab we analyze samples in a few days rather than the months it takes Curiosity. On Earth as on Mars, doing fieldwork well takes a great deal



After taking its first scoops of Martian soil, Curiosity posed for a self-portrait. Stitched together from 63 images, it shows the entire rover and even the imprints in the sand of its scoop and wheels—but not the seven-foot robotic arm that was holding the camera.

NASA/JPL/MSSS



of practice—but on Mars it's at a different level.

For starters, we need a bunch of brilliant engineers just to figure out how to wield the hammer or the drill. At Caltech's Jet Propulsion Laboratory they practiced for years on Curiosity's twin sister, testing tens of thousands of lines of computer code that command the seven-foot robotic arm to make sure they could execute the hundreds of motions required to place a 65-pound drill as gently as a feather on a target the size of a pea. We drilled scores of real rocks, and then we made fake rocks and drilled those too, because we worried that the rocks might be different on Mars. We were certain the weather would be different.

The daily 180-degree-Fahrenheit temperature swings on Mars would cause the whole rover, including the drill bit, to expand and contract. So we had to figure out how to keep it from getting stuck. We worried too whether the powder produced by drilling would clump and clog the tiny tubes and sieves of our onboard chemical lab. We sweated a lot of details.

Then, after we endured the famous "seven minutes of terror" as the sky crane set Curiosity down lightly on Mars, we went through six months of hand-wringing. We had to go easy with our brand-new \$2.5 billion vehicle. When I swing my hammer on Earth, every once in a

From the day we landed, this place looked different from all the others we'd visited on previous missions to Mars. The images reminded us of home.

while I miss and whack the hand that holds the chisel. Band-Aids and time usually solve the problem. On Mars we really don't want the drill or the percussion hammer to hit the rover, ever. The arm was built with as little slop as possible in the joints, and those thousands of lines of software were checked and checked again—but we still didn't know exactly how it would all work on Mars until we tried it. For one thing, gravity there is about one-third as strong as it is on Earth. And so the dozens of activities we had practiced already in California, we practiced again on Mars, in very small steps. If working on Mars weren't so amazing, it would be enough to make you scream sometimes. But after six months we were ready to drill a rock.

SO WHAT IS THIS precious powder we come in search of, like early explorers to the Spice Islands? Curiosity is looking for evidence that life could once have existed on Mars—for environments that could have supported microbes and for organic molecules the microbes might have made. We're not searching for life itself; that would take instruments even more advanced than Curiosity's. Its job is to help us figure out where a future mission should look for life.

A habitable environment includes three important ingredients: water, a source of energy,

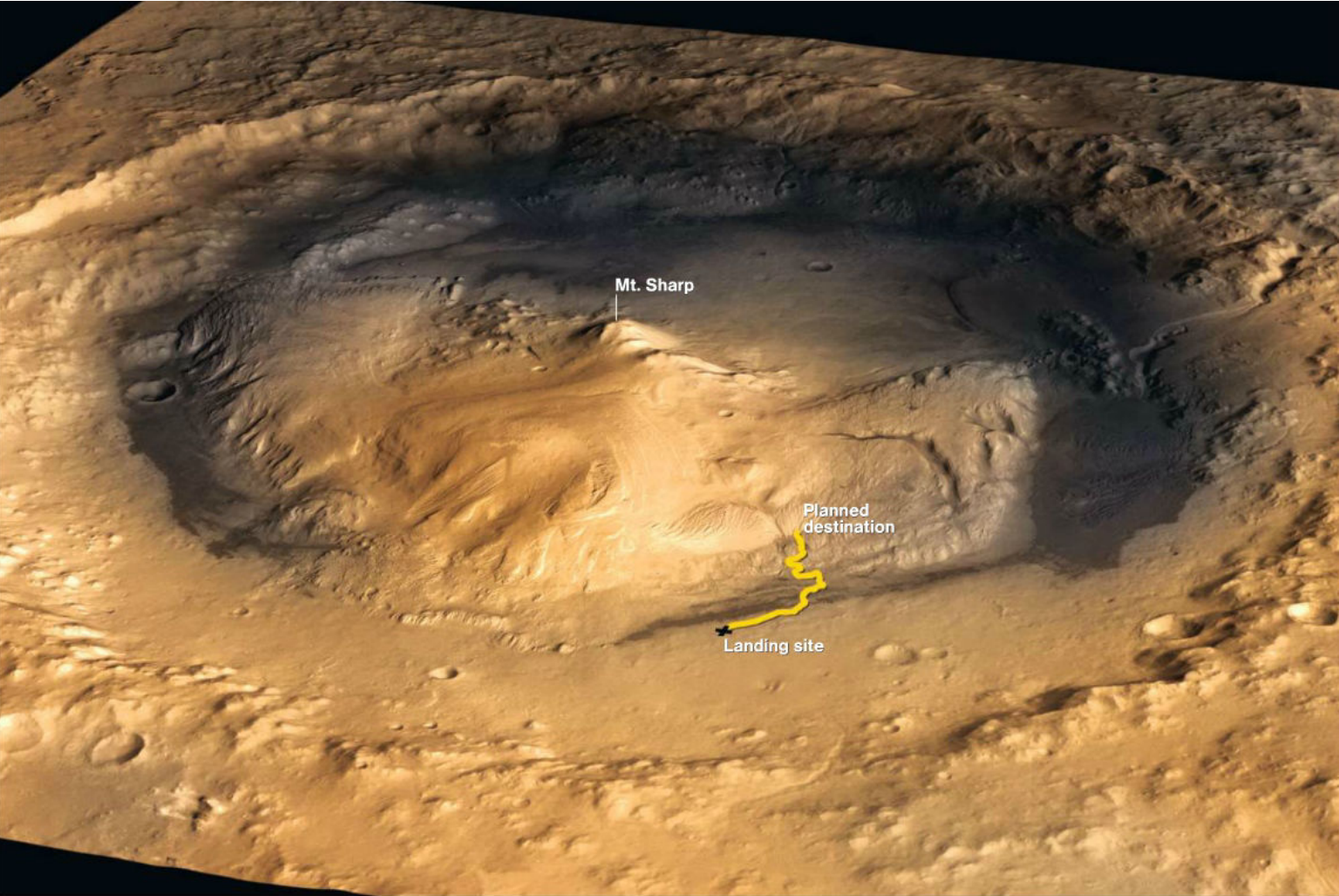
Caltech geologist John Grotzinger is chief scientist for the Curiosity mission. Fieldwork on Earth has taken him to every continent but Antarctica.

and the chemical building blocks of life, such as carbon. Earlier missions proved that Mars was once wet. Orbiters photographed ancient river valleys; rovers found minerals that contained water in their crystal structure. Curiosity is testing for the other two ingredients of habitability. Since the surface of Mars today is not hospitable, we're hunting for ancient rocks that preserve records of a wetter, more Earth-like environment. We're expecting to find such rocks in the stacked sediment layers of Mount Sharp, at the center of Gale crater. But we stumbled on some not far from our landing spot, and so we're drilling there first.

We have to drill to find the good stuff. Drilling gets at material inside the rock that is less degraded and more likely to contain a faithful record of an ancient environment. From the study of Earth's ancient environments, the major focus of my research for more than two decades, I've learned how difficult it is to discover such a record—and especially to find organic molecules that may have been made by ancient organisms.

Even on Earth, which we know was teeming with microbial life billions of years ago, we find the traces in only a few locations. The paradox is that water, an essential ingredient for life, can also destroy organic carbon molecules. In just the places where we might look for life, places where water has flowed through sand or silt, precipitating minerals that bind the particles into rock, the water has often erased the organic traces of life—with rare exceptions. On Earth we've learned how to hunt for those exceptions. It's a long shot, but we're hoping Curiosity will find organic molecules on Mars. They can be made by nonliving processes too, so finding them wouldn't prove there was once life on Mars. But it would tell us where to look.

We've already proved, with the first rock we drilled, that Mars was once habitable. A flat mudstone, shot through with veins of a mineral that formed in water, the rock looks like something from a mining district. Curiosity's analysis showed that the water was not too acidic for life—it would have been drinkable. It contained sulfur compounds that on Earth are an energy source for some microbes. It contained a carbon



source too. We still can't say that the pond our rock formed in, maybe three billion years ago, was inhabited—only that it could have been.

WE DIDN'T NEED a gas chromatograph, though, to sense that Gale crater is full of promise. We just needed to look at the photographs. Within a month of landing, we realized that Curiosity had touched down on an ancient streambed. The stones looked like the ones I'd sent skimming across the creek behind my house in Pennsylvania, back when I was a boy.

Images of distant and unknown places have long inspired explorers and the public too. The photographs made during the Hayden expedition to Yellowstone were an essential reason it was selected as America's first national park in 1872. Photographer William Henry Jackson captured the public's imagination and support by confirming the existence of western landmarks previously regarded as glorified myths: the Grand Tetons, Old Faithful, and strange pools of boiling-hot mud. Half a century later photographer Ansel Adams began his long career of delighting the public with luminous pictures of parks that many would never visit.

Curiosity's photos are like that—inspiring but

Site of an ancient meteor crash, Gale crater is 96 miles across. Curiosity must drive for months, crossing black sand dunes, to begin climbing Mount Sharp. Its rock layers, up to four billion years old—perhaps older than any strata on Earth—may record the fateful time when Mars dried out.

also familiar. Our robot is no Ansel Adams, and Gale crater is not the next national park, but its strikingly Earth-like appearance in Curiosity's postcards has delighted the public and all of us at the Jet Propulsion Lab too. From the day we landed, this place looked different from all the others we'd visited on previous missions to Mars. From the summit of Mount Sharp to the highlands of the crater rim to the close-up of those stones shaped by water in an ancient stream, the images have reminded us of home.

It's a strange and potent thought to have about another planet. Soon after you read this, we should be on our five-mile way across the crater to the mountain. As a traveler on Mars now, I'm feeling the truth of Stevenson's statement: This land is not so foreign. It's a beautiful place to go for a drive. □

THE NEW AGE OF > EXPLORATION

In the new story of the
solar system, the future
is a bit dicey, and

It All Began in Chaos



About 3.8 to 4 billion years ago Earth suffered what scientists call the Late Heavy Bombardment: a mysterious rain of asteroids and comets that pummeled most of its surface. The moon was heavily cratered then too.

SOURCES: STEPHEN MOJZSIS, UNIVERSITY OF COLORADO/NASA LUNAR SCIENCE INSTITUTE; WILLIAM BOTTKER, SOUTHWEST RESEARCH INSTITUTE



4.4 BILLION YEARS AGO

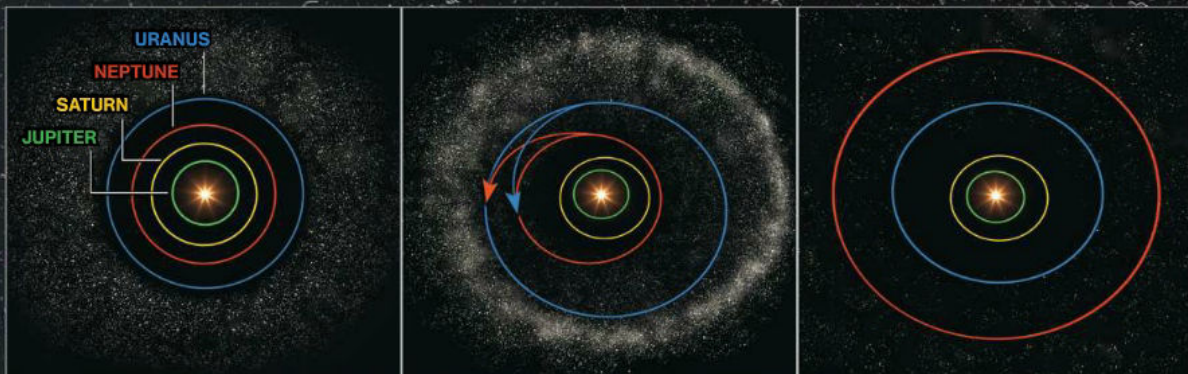
The newborn giants orbit in tight circles; Uranus may be outside Neptune. Their orbits slowly shift as they clear away debris such as comets and asteroids. A dense comet belt lingers beyond Uranus.

3.8 BILLION YEARS AGO

Saturn's orbital period grows to exactly twice Jupiter's. Jupiter's gravity pumps Saturn closer to Uranus and Neptune, which drives them into the comet belt. They fling comets all over—including at Earth.

TODAY

Once Uranus and Neptune sweep most of the comets from their new orbits (and also switch places), the Late Heavy Bombardment ends. The four giants settle into their current, slightly elliptical orbits.





DISTURBING THE GIANTS

The Late Heavy Bombardment of Earth may have resulted from a dramatic disturbance of planetary orbits. That led Neptune (foreground) and Uranus to disrupt a belt of comets, and Jupiter the asteroid belt. According to the Nice model (named for the French town where it was conceived), Jupiter, Saturn, Uranus, and Neptune had been born close together in the solar nebula, a disk-shaped cloud littered with rocky and icy debris. As the four giants' strong gravity sucked in or slung away such debris, their own orbits slowly shifted—until they hit a tipping point.

By Robert Irion
Photographs by Mark Thiessen
Art by Dana Berry

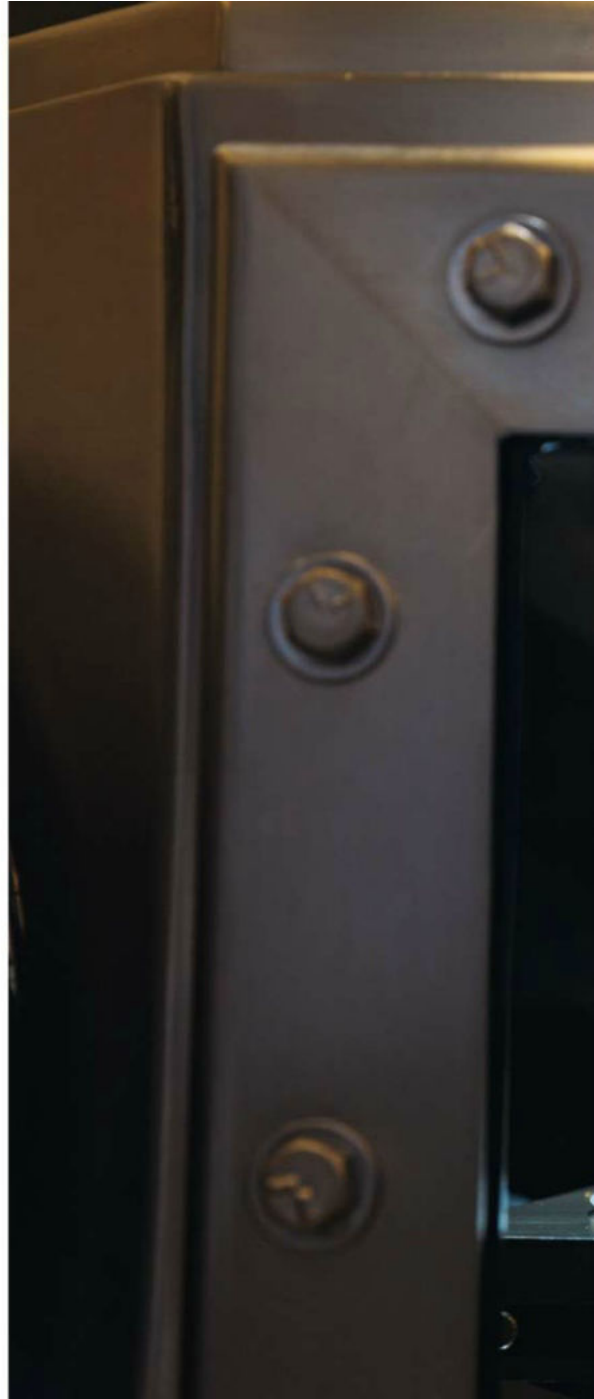
The dust speck had been plucked from the tail of a comet more than 200 million miles away. Now, under an electron microscope in a basement lab at the

University of Washington, its image grew larger, until it filled the computer screen like an alien landscape. Zooming in on a dark patch that looked like a jagged cliff, Dave Joswiak upped the magnification to 900,000. The patch resolved into tiny, jet-black grains. “Some of these guys are only a couple of nanometers in size—that’s amazingly small,” Joswiak said. His tone was reverent. “We think this is the primordial, unaltered material that everything formed from in the solar system.”

The dust speck has a name: Inti, for the Inca god of the sun. It probably spent nearly all of the past 4.5 billion years in a deep freeze beyond Neptune, inside the comet Wild 2 (pronounced VILT-two). Decades ago Wild 2 somehow got nudged into an orbit that drew it in past Jupiter, where it began to disintegrate in the sun’s heat. In January 2004 a NASA spacecraft called Stardust zipped past Wild 2 and snared thousands of dust specks with a trap made of aerogel—a puffy, glassy material that looks like frozen smoke. Two years later a capsule carrying this delicate cargo parachuted into the Utah desert. The Stardust team teased the specks from the gel, stuck them

in their electron microscopes, and stared back at the birth of our solar system. They were stunned by what they saw.

Scientists have long known that the planets, comets, and other bodies orbiting the sun were born, some 4.5 billion years ago, from a spinning disk of dust and gas called the solar nebula. They’ve long assumed that things formed more or less where they orbit now. In the frigid realm beyond Neptune, the material available for making comets would have been a mix of ice and fluffy, carbon-rich dust. But Inti’s dark grains contained exotic minerals—hardy bits of rock and metal such as tungsten and titanium nitride that could only have been forged near the newborn sun, at temperatures of more than 3000 degrees Fahrenheit. Some violent process must





METEORITE Long ago, somewhere between Mars and Jupiter, two asteroids collided. This two-pound meteorite was probably blasted off the larger one, called Vesta. Jupiter's gravity later slung it to Earth, where it landed on the Antarctic snow.

have hurled them into the outer solar system.

"We were dumbfounded," says Donald Brownlee, head of the Stardust team and Joswiak's boss. "It was astounding to find these highest-temperature materials in the solar system's coldest bodies. The solar system was literally turning itself inside out."

WHEN MOST OF US were growing up, the solar system seemed reliable and well behaved. "There were nine planets orbiting in well-determined orbits like clockwork, forever," says Renu Malhotra of the University of Arizona. "Forever in

the past, and forever in the future." Planetarium displays and the lovely mechanical devices called orreries embodied this idea, which went back to Isaac Newton. In the late 17th century Newton showed that a planet's orbit could be calculated from its gravitational interaction with the sun. Soon clockmakers were building increasingly elaborate orreries, with brass planets that circled the sun on unchanging pathways.

Newton himself knew that reality was messier. The planets, he recognized, must also interact with one another. Their gravitational tuggings are far weaker than those of the sun, but over



COMET DUST In a NASA clean room a scientist examines traps containing dust snared by the Stardust probe as it flew by the comet Wild 2. Each speck left a hair-size track (right) as it plunged into the puffy aerogel at more than 13,000 miles an hour.

time they affect the paths of neighbors. As a result, as Brownlee puts it, “there’s no such thing as a circular orbit.” In principle the relentless pull of gravity can amplify these small deviations until orbits migrate, cross, or otherwise go haywire. Newton concluded that God must step in from time to time to fix the clockwork. But he couldn’t say when. Even he who invented calculus was defeated by the “n-body problem”: He had no formula for calculating into the distant future the orbits of multiple bodies that were all pulling on one another.

In practice no one saw evidence that planetary orbits had ever changed. So the clockwork

Robert Irion directs the science writing program at the University of California, Santa Cruz. Mark Thiessen’s photographs of methane, an invisible gas, appeared in the December issue. Artist Dana Berry created the December 2009 cover and this month’s.

solar system stuck with us—enduringly stable, it seemed, even without fixes from the Creator.

But a far more dramatic view has arisen in the past decade or so. While the findings from Stardust indicate the solar system was turned inside out during infancy, many scientists now think it also went through a raucous adolescence: Hundreds of millions of years after they formed, the biggest planets swept into new orbits, casting large rocks and comets every which way. In this view the scarred surface of the moon is lingering testimony to a period of epic mayhem.

“Who would have thought the giant planets might move, that the entire layout of the solar system could change?” says Alan Stern of the Southwest Research Institute in Boulder, Colorado. Some signs were there, Stern says. But it took new telescope surveys to reveal them, along with “digital orreries”—clever algorithms that apply brute computing power to calculating







OUR MOON IS BORN

The birth of the planets 4.5 billion years ago was extremely violent. They grew to full size by absorbing rival planet embryos in a series of titanic collisions—one of which probably gave Earth its moon (below). The moon's large size, low density, and other features suggest that it emerged from an explosion of debris after a Mars-size protoplanet struck Earth, vaporizing itself and part of Earth's rocky mantle (left). According to one recent hypothesis, the moon had a little sister at first.

BIRTH Rocky debris blasted into orbit coalesces into a moon—or maybe two—in less than a century. Most of the incoming protoplanet's iron sank into Earth's core, so the moon is less dense than Earth.

MOVING OUT Lunar gravity raises a tidal bulge on Earth; its spinning in turn accelerates the moon, causing it to spiral slowly outward. A sister moon, about a third as wide, orbits at a distance.

SPLAT Within tens of millions of years the moon reels in its sister. Splatting onto the moon's far side, it creates highlands there—a striking contrast to the low plains, called maria, on the side we see.



If an asteroid or comet approached Neptune, the planet's powerful gravity might fling it toward the sun or out of the solar system, in a cosmic version of crack the whip.

the past and future orbits of the planets.

The first clue came from Pluto. The oddball of the solar system, it dips far above and below the pancake-like plane in which the eight planets travel; it swoops on an elongated orbit that takes it from 30 to 50 times Earth's distance from the sun. But the most curious thing about Pluto is its bond with Neptune. It's called a resonance: For every three times that Neptune orbits the sun, Pluto orbits twice, and in such a way that the bodies never approach each other.

In 1993 Renu Malhotra figured out how that exact synchrony could have evolved. She proposed that when the solar system was young and full of asteroids and comets, Neptune was closer to the sun. If one of those bodies approached Neptune, the planet's powerful gravity might either fling the object closer to the sun or out of the solar system entirely, in a cosmic version of crack the whip. Because action begets reaction, Neptune's orbit would shift a tiny bit too. A human, even a Newton, could never calculate the effect of trillions of such interactions—but Malhotra's computer model showed that on average they would compel Neptune to migrate away from the sun. In her scenario, that led it to “capture” Pluto, which was already farther out, and sweep it into gravitational lockstep.

Her colleagues were doubtful, but Malhotra was proved right within a decade. In the Kuiper belt, a dark region extending far beyond Neptune, telescopes unveiled bunches of Plutinos—icy dwarf worlds that have the same two-to-three

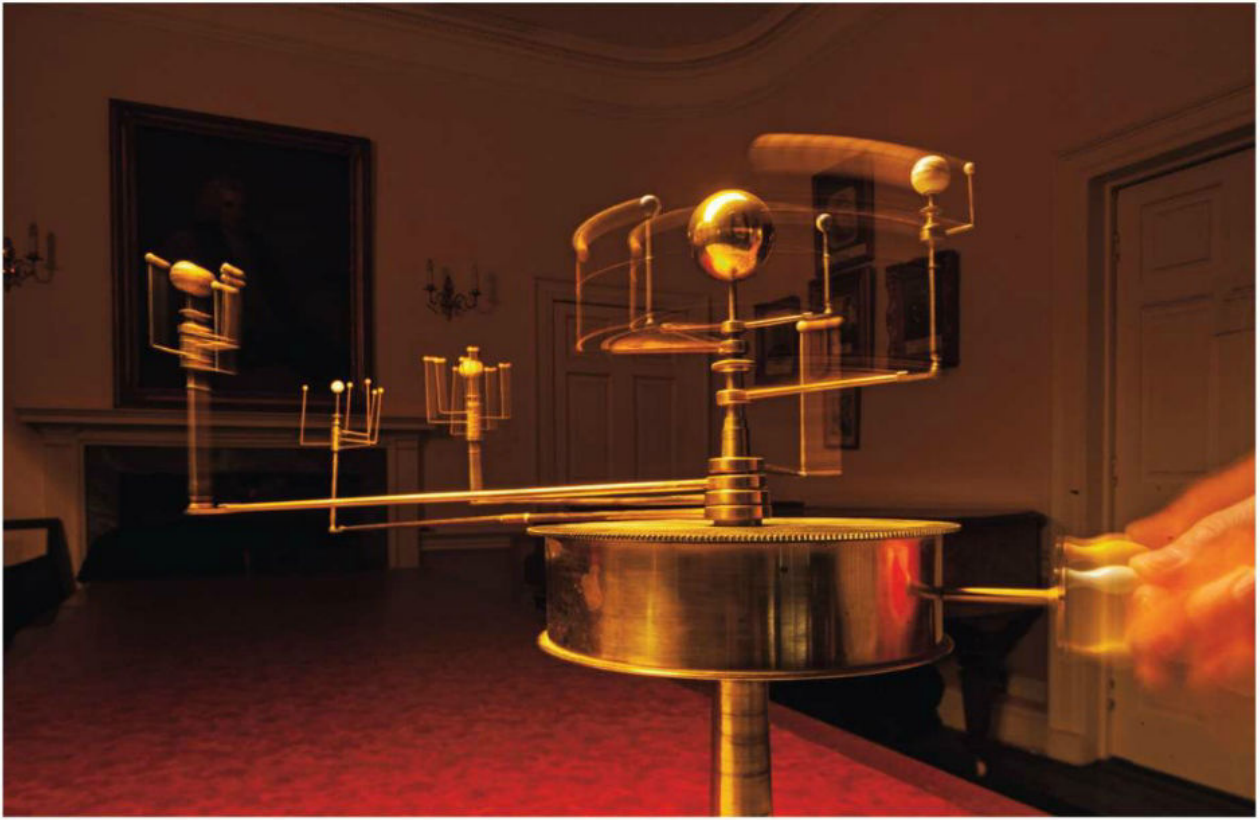
resonance with Neptune. That could only have happened, says Malhotra, if Neptune had advanced toward the Kuiper belt like a gravitational snowplow, piling up dwarf planets into new orbits. “Once the Plutinos were discovered, it was a slam dunk,” she says. “Planet migration practically became a textbook idea.”

The notion of migrating planets came along at a time when planetary scientists were puzzled by several other features of the solar system. By the early 2000s they had long since realized that the birth pangs of the solar system had been violent. The planets had not condensed gently from the solar nebula; instead they had grown to full size by absorbing planetesimals—rocky asteroids, icy comets, and larger objects—that smashed into them at high speed. According to one theory, the moon coalesced from the spray of molten rock that was blasted into orbit when a body the size of Mars collided with Earth. All this probably happened in the first 100 million years.

The puzzle was that the extreme violence didn't end then. Many hundreds of millions of years later, the moon suffered a series of major impacts that left it permanently scarred with huge craters. This so-called Late Heavy Bombardment would have pounded Earth even more viciously. Scientists had no good explanation for what sparked it, since by the time it happened, the planets had swept their orbits mostly clean of debris.

Telescopes were unveiling a similar enigma in the Kuiper belt. Besides Plutinos, it was littered with bodies on wildly different orbits. Some of the bodies were grouped in a flat disk, some in a puffy doughnut-shaped cloud; others were on orbits even more crazily eccentric (the technical term for elongated) than Pluto's. “It looked like a train wreck,” says Harold Levison, Stern's colleague at the Southwest Research Institute. The smooth outward migration of Neptune that Malhotra had used to explain the Plutinos would not have strewn debris so widely.

Meanwhile, astronomers had started to discover planets around other stars—and to radically expand their notions of what's possible in a planetary system. Hundreds of extrasolar



CLOCKWORK The old models called orreries depicted an ever predictable solar system. The real one is more random: Moving a pencil across your desk today, says one astronomer, can shift Jupiter halfway around its orbit a billion years from now.

planets have now been detected. Some are in tightly bunched orbits, much closer together than the planets in our solar system. Some are Jupiter- or Neptune-size worlds that race on insanely hot orbits close to their suns. Others loop deep into space on weird trajectories—on average the orbits of extrasolar planets are more eccentric than those in our solar system. Some planets even float freely in interstellar space.

None of this is what you would expect from planets that were born in a spinning disk around a star and stayed quietly in their birthplace. That process should produce well-spaced, near-circular orbits, like the ones in the brass orreries. Clearly many planets had migrated, but smooth migrations didn't seem to account for extreme orbits and late bombardments, at least not to Levison. He began to suspect that our solar system's history had been anything but smooth—that it had somehow endured a “global

gravitational instability,” as he now calls it. In 2004 he gathered with three colleagues on sabbatical in Nice, France, to try to work out how.

LEVISON, WHO GOES BY “Hal,” is a burly man with thin, graying hair pulled back into a ponytail and an untamed Santa-style beard. He's both serious and impish; his Boulder office contains lush old illustrations of planetary orbits, an Albert Einstein action figure, and a model of Gort, the robot from *The Day the Earth Stood Still*. He's fond of giving provocative talks and will sometimes wear a catcher's mask to ward off brickbats from the audience. “What I'm going to say is really absolutely crazy,” he said at the start of a recent seminar. “If we publish this, my career might be over.” He could have made the same remark back in 2004 about what is now called the Nice model—the hypothesis that he and his colleagues, including Alessandro Morbidelli of

Everything happened slowly—until Saturn began completing exactly one orbit for every two of Jupiter’s. That triggered a devastating cascade.

the Côte d’Azur Observatory in Nice, developed on the basis of dozens of computer simulations.

In essence Levison’s team proposed that our solar system’s four giant planets—Jupiter, Saturn, Uranus, and Neptune—had started out much more closely packed together, on nearly circular orbits, with the latter three closer to the sun than they are now. Early on they were embedded in the disk-shaped solar nebula, which was still full of icy and rocky debris. As the planets absorbed those planetesimals or flung them away after close encounters, they cleared gaps in the disk.

Because the planets were also tugging on one another, the whole system was fragile—“almost infinitely chaotic,” Levison says. Instead of each planet being linked only to the sun by a brass arm, it’s as if they were all linked by gravitational springs as well. The most powerful one linked the two biggest bodies, Jupiter and Saturn. A yank on that spring would jolt the whole system.

And that, the team believes, is what happened when the solar system was about 500 million to 700 million years old. As the planets interacted with planetesimals, their own orbits shifted. Jupiter moved slightly inward; Saturn moved slightly outward, as did Uranus and Neptune. Everything happened slowly—until at a certain point Saturn was completing exactly one orbit for every two of Jupiter’s.

That one-to-two resonance wasn’t stable like the one between Neptune and Pluto; it was a brief, vigorous yank on the spring. As Jupiter and Saturn approached and pulled each other repeatedly at the same point in their orbits, those near-circular orbits were stretched into the ellipses we see today. That soon ended the precise resonance, but not before Saturn had moved close enough to Uranus and Neptune to accelerate them. Those two planets hurtled violently outward. In about half the Nice team’s simulations, they even swapped places.

As Uranus and Neptune plowed through zones of the solar system that were still full of icy planetesimals, they triggered a devastating cascade. Ice balls were catapulted in all directions. The giant planets captured a few as oddly orbiting moons. Many objects, perhaps including the comet Wild 2, were scattered into the Kuiper belt. An untold number—perhaps a trillion—were banished even farther to the Oort cloud, a vast cocoon of comets reaching halfway to the next star. A lot of comets were also hurled into the inner solar system, where they crashed into planets or fell apart in the heat of the sun.

Meanwhile the giant-planet migrations also disrupted the rocky asteroid belt between Jupiter and Mars. Scattering asteroids joined comets from farther out to create the Late Heavy Bombardment. A recent NASA mission called GRAIL documented how badly our moon suffered then and earlier in its history: Its entire crust was deeply fractured. Earth would have caught even more flak, but shifting tectonic plates have erased the craters. Any early life could only have survived deep underground.

The worst of the Late Heavy Bombardment was over, according to the Nice model, in less than 100 million years. But recent work by Bill Bottke of the Southwest Research Institute suggests that ongoing impacts may have disrupted life for up to two billion more years. When an asteroid slams into Earth, tiny droplets of molten

SURVIVOR Vesta never grew into a planet, but it endured eons of impacts and is now, at more than 300 miles across, the third largest asteroid in the belt between Mars and Jupiter. Six percent of the meteorites that fall on Earth are chips off Vesta.



rock are lofted high into the atmosphere, and they later rain out as solid, glassy beads called spherules. Deposits of spherules from the six-mile-wide asteroid that hit the Yucatán some 65 million years ago, wiping out the dinosaurs, have been discovered all over the world. So far at least a dozen comparable spherule beds have been found that date from a series of impacts between 1.8 billion and 3.7 billion years ago.

The computer simulations by Bottke's team trace the source of those impacts to a now vanished inner rim of the asteroid belt, which shed asteroids for two billion years after Jupiter disturbed it. According to Bottke, as many as 70 may have struck Earth, each comparable to the one that extinguished the dinosaurs.

"Solar system evolution is dynamic," Levison says. "It's violent. Our solar system is probably on the mild side compared with what happens elsewhere. You probably need that mildness in order to have a habitable planet."

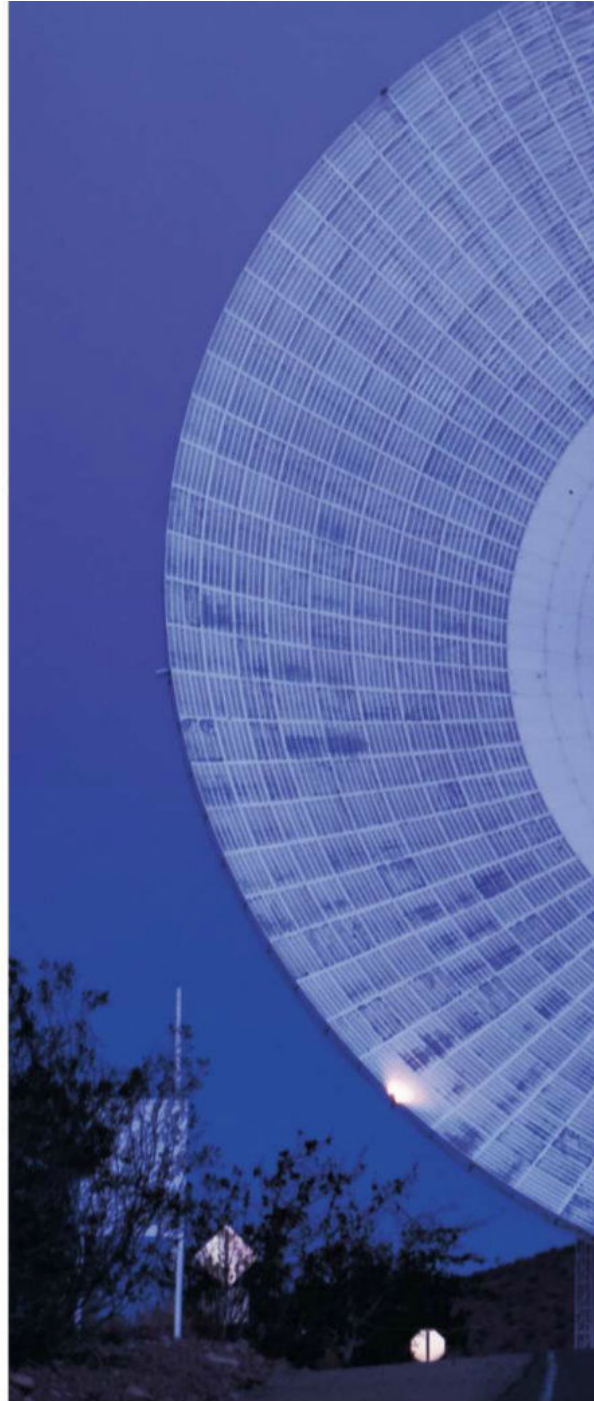
THE NICE MODEL is a hypothesis, and not all scientists are convinced it's true. Everyone now agrees that at least some planets migrated, but whether that set off a violent solar-system-wide paroxysm is up for debate. "It's a fascinating concept," says Donald Brownlee. "It must happen in places, around other stars. Whether or not it happened here, we don't know for sure." It's clear that comet particles like Inti were blasted outward from near the sun, he says, but the planets may have shifted more gently.

The key to testing the Nice model is mapping. Charting the composition and orbits of distant objects should reveal whether and how the planets cast them there. Stern is leading a NASA mission called New Horizons that will send an unmanned probe past Pluto and its five known moons in July 2015. From there Stern hopes to redirect New Horizons to examine at least one other body in the Kuiper belt.

Powerful new telescopes planned for the next decade will expose far more objects in the Kuiper belt. They may also peek into the Oort cloud, which Stern calls the solar system's attic. The debris cast there by Jupiter may include some

lost planets. "I think the Oort cloud will blow our minds," says Stern. "It will be littered with planets. I think we'll find lots of Marses and Earths out there."

What about the future of the planets we know? Forecasting the solar system is like forecasting the weather. There's so much randomness in the system, says theorist Greg Laughlin of the University of California, Santa Cruz, that the forecast—as well as any historical reconstruction—has to be given in probabilities. Scientists are as certain as they can be that the four giant planets have finished wandering and will still be on the same orbits five billion years from now, when the aging sun is expected to balloon outward and engulf the inner planets.





RADAR California's 230-foot-wide Goldstone antenna makes radar images that reveal an asteroid's size, speed, and distance—and whether it's headed near Earth. In February a 130-foot rock passed within 17,200 miles of Earth, closer than some satellites.

It's a little bit less certain that the inner planets—Mercury, Venus, Earth, and Mars—will still be around to die that way.

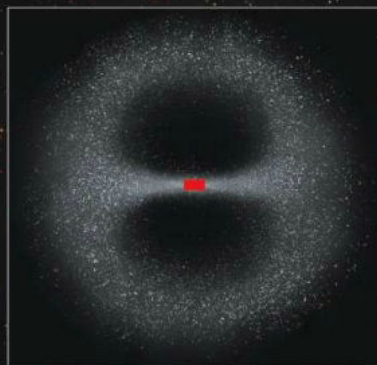
“There is a one percent chance the inner solar system will go dramatically unstable during the next five billion years,” says Laughlin. The problem is a weird long-distance connection between Jupiter and Mercury. When Jupiter's closest approach to the sun lines up with Mercury's noticeably squashed orbit in just the right way, Jupiter exerts a slight but steady tug. Over billions of years this gives Mercury a 1-in-100 chance of crossing the orbit of Venus. There is

a further 1-in-500 chance that if Mercury goes nuts, it will also perturb the orbit of Venus or Mars enough for one of them to hit Earth—or miss it by several thousand miles, which would be almost as bad. “The entire Earth would get stretched and melted like taffy,” says Laughlin, eagerly demonstrating with his hands.

That faint risk of apocalypse—a 1-in-50,000 chance that the Earth will succumb to orbital chaos before the sun incinerates it—is our legacy of the solar system's youth, when it turned inside out. “If you give gravity enough time,” says Levison, “it will do stuff like this.” □

THE SOLAR SYSTEM'S ATTIC


During the early chaos of the solar system, Jupiter is thought to have flung trillions of comets and perhaps a few planets into deep space. Only lightly bound to the sun, they now form a spherical cloud, called the Oort cloud, around the solar system we know. In this view from the cloud, the sun and its familiar retinue are a small, bright swirl, and an undiscovered planet looms in the foreground. A new telescope being developed in Chile might reveal such planets.



TWO-PART CLOUD

Long-period comets come from the Oort cloud. Their orbits suggest that the cloud (seen here in cross section) is a spherical shell close to a light-year across, bisected by a doughnut. The rest of the solar system (red) lies in the doughnut hole.





*From a glue-covered stick on Cyprus hangs a life,
and a question: How can we stop the slaughter of
songbirds migrating across the Mediterranean?*

LAST

A whitethroat, en route to winter grounds in Africa, is caught in a sticky trap called a lime stick.



SONG

A low-angle photograph of a man in a light-colored shirt looking upwards towards a tall palm tree. The scene is set in an oasis with many other palm trees and green reeds in the foreground. The lighting is bright, suggesting a sunny day.

EGYPT

After crossing the Mediterranean on their way south, golden orioles must brave more than a thousand miles of Saharan desert. The Al Maghrah oasis is a welcome spot of green in this sea of sand. But hunters lie in wait for the weary birds.







ITALY

This poacher's tray of frozen songbirds, most only inches long, was confiscated by forest rangers. Illegally hunted birds are secretly served as a delicacy in restaurants and homes.

I N A BIRD MARKET IN THE MEDITERRANEAN TOURIST TOWN OF MARSA MATRUH, EGYPT, I WAS INSPECTING CAGES CROWDED WITH WILD TURTLEDOVES AND QUAIL WHEN ONE OF THE BIRDSSELLERS SAW THE DISAPPROVAL IN MY FACE AND CALLED OUT SARCASTICALLY, IN

Arabic: “You Americans feel bad about the birds, but you don’t feel bad about dropping bombs on someone’s homeland.”

I could have answered that it’s possible to feel bad about both birds and bombs, that two wrongs don’t make a right. But it seemed to me that the birdseller was saying something true about the problem of nature conservation in a world of human conflict, something not so easily refuted. He kissed his fingers to suggest how good the birds tasted, and I kept frowning at the cages.

To a visitor from North America, where bird hunting is well regulated and only naughty farm boys shoot songbirds, the situation in the Mediterranean is appalling: Every year, from one end of it to the other, hundreds of millions of songbirds and larger migrants are killed for food, profit, sport, and general amusement. The killing is substantially indiscriminate, with heavy impact on species already battered by destruction or fragmentation of their breeding habitat. Mediterraneans shoot cranes, storks, and large raptors for which governments to the north have multimillion-euro conservation projects. All across Europe bird populations are in steep decline, and the slaughter in the Mediterranean is one of the causes.

Italian hunters and poachers are the most notorious; for much of the year, the woods and wetlands of rural Italy crackle with gunfire and songbird traps. The food-loving French continue

to eat ortolan buntings illegally, and France’s singularly long list of huntable birds includes many struggling species of shorebirds. Songbird trapping is still widespread in parts of Spain; Maltese hunters, frustrated by a lack of native quarry, blast migrating raptors out of the sky; Cypriots harvest warblers on an industrial scale and consume them by the plateful, in defiance of the law.

In the European Union, however, there are at least theoretical constraints on the killing of migratory birds. Public opinion in the EU tends to favor conservation, and a variety of nature-protection groups are helping governments enforce the law. (In Sicily, formerly a hot spot for raptor killing, poaching has been all but eliminated, and some of the former poachers have even become bird-watchers.) Where the situation for migrants is *not* improving is in the non-EU Mediterranean. In fact, when I visited Albania and Egypt last year, I found that it’s becoming dramatically worse.

February 2012 brought eastern Europe its coldest weather in 50 years. Geese that normally winter in the Danube Valley flew south to escape it, and some 50,000 of them descended on the plains of Albania, starving and exhausted. Every one of them was exterminated. Men using shotguns and old Russian Kalashnikovs mowed them down, while women and children carried the carcasses into towns



EGYPT

A young Bedouin in the Western Desert shows off a sample from his morning haul: a golden oriole rich in fat after a summer in Europe. Bedouin tend to eat what they catch. Plucked and fried, this two-ounce bird will provide two bites of meat.

for sale to restaurants. Many of the geese had been banded by researchers to the north; one hunter told me he'd seen a band from Greenland. Although nobody in Albania is going hungry, the country has one of the lowest per capita incomes in Europe. The unusual influx of saleable geese was literally a windfall for local farmers and villagers.

The easternmost of Europe's migratory flyways passes through the Balkans, and in Albania the Adriatic coastline, which is otherwise forbiddingly mountainous, opens into an extraordinarily rich system of wetlands, lakes, and coastal plains. For millennia birds making the northward journey from Africa were able to rest and refuel here before struggling on over the Dinaric Alps to their breeding grounds, and

to stop here again in the fall before recrossing the Mediterranean.

Under the 40-year Marxist dictatorship of Enver Hoxha, totalitarianism destroyed the fabric of Albanian society and tradition, and yet this was not a bad time for birds. Hoxha reserved the privileges of hunting and private gun ownership for himself and a few trusted cronies. (To this day the national Museum of Natural History displays bird trophies of Hoxha and other members of the politburo.) But a handful of hunters had minimal impact on the millions of migrants passing through, and the country's

Novelist Jonathan Franzen's latest book is Farther Away. This is AP staff photographer David Guttenfelder's third story for the magazine.



EGYPT

At the market in El Daba, dead songbirds are counted. Merchants sell both live and dead birds at specialty markets in towns along the coast. When customers purchase them live, the merchants kill and pluck them on the spot.

command-economy backwardness, along with its repellence to foreign beach tourists, ensured that its wealth of coastal habitat remained intact.

Following Hoxha's death, in 1985, the country underwent an uneasy transition to a market economy, including a period of near anarchy in which the country's armories were broken open and the military's guns were seized by ordinary citizens. Even after the rule of law was restored, Albanians kept their guns, and the country remained understandably averse to regulation of all kinds. The economy began to grow, and one of the ways in which a generation of younger men in Tirana expressed their new freedom and prosperity was to buy expensive shotguns, by the thousands, and use them to do what formerly only the elite could do: kill birds.

In Tirana, a few weeks after the big February freeze, I met a young woman who was very unhappy with her husband's new hunting hobby. She told me they'd had a fight about his gun, which he'd had to borrow money to pay for. He kept the gun in their 1986 Mercedes, and she described how she'd once watched him pull over to the side of a road, jump out of the car, and start shooting at little birds on a power line.

"I'd like to understand this," I said.

"You won't!" she said. "We've talked about it, and I don't understand it." But she called her husband on her cell phone and asked him to join us.

"It's become fashionable, and my friends talked me into it," the hunter explained to me, somewhat sheepishly. "I'm not a real hunter—you can't become a hunter at 40. But being a new

GOLDEN ORIOLE
Oriolus oriolus



Hiding in densely foliated trees, orioles are more often heard than seen. Hunters seek them in the open, watching for their bright colors.

one, and feeling good about owning a licensed weapon, a very good powerful gun, and never having killed any birds before, it was fun at first. It was like when summer comes and you feel like jumping in the ocean. I would go out on my own and drive up into the hills for an hour. We don't have well-identified protected areas, and I'd shoot whatever I could. It was spontaneous. But it gets less joyful when you think about the animals you're killing."

"Yes, what about that?" I said.

The hunter frowned. "I feel very uncomfortable with the situation. My friends are saying it now too: 'There are no birds; we walk for hours without seeing any.' It's really scary. At this point I'd be happy if the government put a stop to all hunting for two years—no, five years—to let the birds recover."

There would be precedent for a fiat like this: Seven years ago, when coastal drug and human smuggling became a problem, the government simply banned most private boats and yachts. But electoral power in Albania is narrowly balanced between two major political parties, each of which is loath to impose potentially unpopular regulation on an issue of minor concern to most voters.


There is, indeed, only one serious bird advocate in Albania, Taulant Bino, who is also the country's only real bird-watcher. Bino is the deputy minister of the environment, and one morning he took me out to Divjaka-Karavasta National Park, the crown jewel of Albanian coastal preserves, a vast area of outstanding beach and wetland habitat. It was mid-March, a time when hunting is banned throughout the country, and the park (where hunting is prohibited year-round) ought to have been full of wintering and migrating waterfowl and waders. Except for one pond defended by fishermen, however, the park was strikingly devoid of bird-life; there weren't even any mallards.

Driving along the beach, we soon saw one reason why: A group of hunters had put out decoys and were shooting cormorants and godwits. The park's manager, who was escorting us, angrily told the hunters to leave, at which point one of them took out a phone and tried to call a friend in the government. "Are you crazy?" the park manager shouted at him. "Do you realize that I'm here with the deputy minister of the environment?"

Bino's ministry has safeguarded, at least on paper, sufficient habitat to sustain healthy populations of migratory and breeding birds. "When conservationists saw that the economic development might hamper the biodiversity," Bino told me, "they thought they'd better expand the network of protected areas before they were threatened with development. But it's difficult to control people who are armed—you also need the police. We closed one area here in 2007, and 400 hunters showed up, shooting everything. The police came in and confiscated some weapons, but after two days they said to us, 'This is your problem, not ours.'"

Unfortunately, the old communist joke still applies to forestry officials responsible for the protected areas: The government pretends to pay them, and they pretend to work. As a result, the laws are not enforced—a fact that Italian hunters, limited by EU regulations at home, were quick to recognize and exploit after Hoxha's death. During my week in Albania I didn't visit a protected area in which there were not Italian hunters, even though the hunting season had ended, even in unprotected areas. In every case the Italians were using illegal high-quality bird-sound playback equipment and shooting as much as they wanted of whatever they wanted.

On a second visit to Karavasta, without Bino, I saw two men in camouflage getting into a boat with guns, obviously hurrying to push off before I could speak to them. An Albanian helper of




Northern bald ibis
Geronticus eremita
Wingspan 4 feet
Migrates as far as 1,900 mi

A few hundred survive in the wild around the Mediterranean. Hunters have shot a third of those that researchers are trying to reintroduce to Italy.



Saker falcon
Falco cherrug
Wingspan 3.5 to 4 feet
Migrates as far as 2,500 mi

One of the rarest raptors, it's captured for use as a hunter in the sport of falconry in the Middle East and Central Asia.




Ortolan bunting
Emberiza hortulana
Length 6.3 inches
Migrates as far as 3,600 mi

A French delicacy, ortolans—now illegal to catch or sell—are netted, fattened up, drowned in brandy, then roasted.

● Critically endangered
● Endangered
● Least concern

PERILOUS JOURNEYS

It's an extraordinary feat. Three billion birds of some 300 species—songbirds, waterbirds, raptors—migrate thousands of miles for summer breeding in Eurasia, then return to Africa for winter. They navigate by cues still not fully understood: the sun, the stars, landforms, scents, even Earth's magnetic field. Almost all their numbers are falling, mainly due to habitat loss. The additional toll of illegal and indiscriminate hunting claims hundreds of millions of birds a year.



Hoopoe
Upupa epops
Length 11 inches
Migrates as far as 3,000 mi

Named for the sound of its song, it heralds spring in southern Europe and is the national bird of Israel.



Red-backed shrike
Lanius collurio
Length 7 inches
Migrates as far as 6,800 mi

Abundant overall yet now rare in Great Britain, in part because its patterned eggs were so sought by collectors.



Red-breasted goose
Branta ruficollis
Length 22 inches
Migrates as far as 3,500 mi

Illegally shot as it flies from breeding grounds on Russia's Arctic tundra to its winter home on the western Black Sea coast.

WHY BIRDS DIE

Icons show the chief reason wild birds are killed in a country. Birds hunted for "leisure" may also be eaten, but many are left where they fall.

Human consumption
Farm protection
Illegal trade
Hunting for leisure

KNOWN ILLEGAL TRADE ROUTE

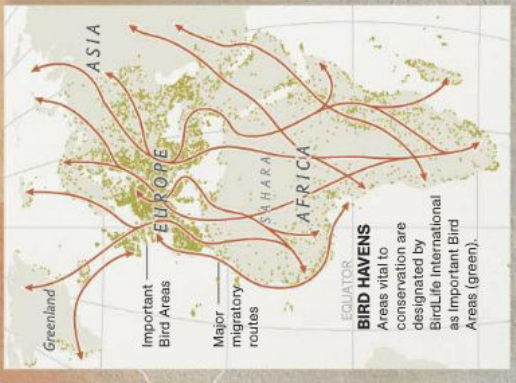
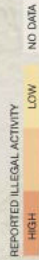
WHERE THEY GATHER

Green areas along the migration flyways show where birds mass at favorable crossings or stop to rest and feed. Hunters gather there too.

- MAJOR MIGRATORY FLYWAY
- Killing hot spots
- CONGREGATION AREAS

TOP OFFENDERS

BirdLife International creates these rankings with data from countries that have signed bird-protection acts and from other reports.



MAJOR MIGRATION CROSSINGS

- A SOUTHERN SPAIN**
The shortest route across the Mediterranean attracts large numbers of soaring raptors, which rely on updrafts created by heat rising from land.
- B CENTRAL MEDITERRANEAN**
Island-hopping migrants suffer most on Malta, infamous for illegal hunting—for trophies, for food, and for entertainment.
- C ADRIATIC**
"Hardly any bird species is safe," a 2009 study says of this flyway. Illegal hunting in the Balkans is boosted by Italians who come to shoot where enforcement is lax.
- D EASTERN MEDITERRANEAN**
The most heavily traveled route on this map funnels birds east to the Siberian Arctic and west through the Bosphorus.

FERNANDO G. BAPTISTA, VIRGINIA W. MASON, AND DANIELA SANTAMARINA, NIGM STAFF; FRANK GERRITSYUS, SOURCES: BIRDLIFE INTERNATIONAL, NICH NATIONAL AGENCY FOR NATURE CONSERVATION (ALGERIA); ENVIRONMENT GENERAL AUTHORITY (LIBYA); LIBYAN SOCIETY FOR BIRDS; NATURE CONSERVATION EGYPT; ASSOCIATION "LES AMIS DES OISEAUX" (TUNISIA); PETER LACK, BRITISH TRUST FOR ORNITHOLOGY; SMITHSONIAN INSTITUTION, NATIONAL MUSEUM OF NATURAL HISTORY, UNION OF BIRDS





EGYPT

Nets drape the first trees that migrating birds see after crossing the Mediterranean. The birds fly into the open end of the net and can't find their way out, which makes it easy for this boy to catch a chiffchaff.

theirs, standing on the beach, told me that they were Albanians, but when I called out to them, they shouted back in Italian.

"OK, they're Italians," the helper admitted as they motored away from us. "Cardiologists from Bari, very well equipped. They were out here from dawn to midnight yesterday."

"Do they know the hunting season is over?" I asked.

"They're smart men."

"How did they get into the national park?"

"It's an open gate."

"And who gets paid off? The guards?"

"Not the guards. It's higher up."

"The park manager?"

The helper shrugged.

Albania was once ruled by Italy, and many Albanians still view Italians as models of sophistication and modernity. Beyond the very considerable immediate damage that Italian tourist hunters do in Albania, they've introduced both an ethic of indiscriminate slaughter and new methods of accomplishing it—in particular the use of playback, which is catastrophically effective in attracting birds. Even in provincial villages, Albanian hunters now have MP3s of duck calls on their cell phones and iPods. Their new sophistication, coupled with an estimated 100,000 shotguns (in a country of three million) and a glut of other weapons that can be used opportunistically, has turned Albania into a giant sinkhole for eastern European migratory biomass: Millions of birds fly in and very few get out alive.

The smart or lucky ones avoid the country. On a beach in Velipoja I watched large flocks of garganeys fly back and forth in distress, far offshore, further exhausting themselves after crossing the Adriatic, because local hunters in well-spaced beach blinds prevented them from reaching the wetlands where they could feed. Martin Schneider-Jacoby, who was a bird specialist for the German organization EuroNatur until his death last summer, described to me how flocks of cranes, approaching Albania from the sea, divide in two by age group. The adult birds continue flying at high altitude, while inexperienced

A close-up photograph of a European robin caught in a metal snap trap. The bird is positioned on the right side of the frame, with its body and tail feathers visible. Its neck and one foot are pinned to the metal trap, which is a simple wire structure. The ground is covered with a thick layer of brown, fallen leaves and twigs, creating a natural, somewhat cluttered background. The lighting is soft and natural, highlighting the textures of the bird's feathers and the surrounding forest floor.

ITALY

A metal snap trap operates like a mousetrap, with berries as the bait. Catching birds this way is illegal, but poachers still use the traps in the northern woods. This European robin, fatally pinned by its neck and foot, was discovered by rangers on patrol.





COMMON KESTREL
Falco tinnunculus

Kestrels and other raptors prey on smaller birds, and as a consequence often become trapped in nets and on lime sticks set for songbirds.

first-year birds, seeing attractive habitat below, descend until shots ring out—there's always somebody ready to take potshots—and then rise again and follow the adults. "They're coming from the Sahara," Schneider-Jacoby said, "and they have 2,000-meter mountains they have to cross. They need the rest. They might still have the energy to get over the mountains, but maybe not then for successful breeding."

Across the Albanian border, in Montenegro, Schneider-Jacoby showed me the extensive salt pans at the town of Ulcinj. Until recently, Montenegrin hunters kept the pans as empty of birds as Albania's "protected" areas, just a few miles away, but a nonprofit, the Center for Protection and Research of Birds of Montenegro, has provided for a single ranger to report poachers to the police, and the results have been dramatic: birds as far as the eye can see, thousands of waders, thousands of ducks, all busily feeding. Spring migration, always awe-inspiring, had never seemed to me more so.

"Eurasia cannot afford a sinkhole like Albania," Schneider-Jacoby said. "We're too good at killing these animals, and we still haven't learned in Europe how to have a system that will allow birds to survive. Hunting bans are the only thing that seems to work right now. If they stop the hunting here, they'll have the best habitat in Europe. People will come to Karavasta to see the resting cranes."

The situation in Albania isn't hopeless. Many new hunters seem aware that something has to change; better environmental education and the coming growth of foreign tourism may increase demand for unspoiled natural areas; and bird populations will rebound quickly if the government enforces the law in protected areas. When I took the hobbyist hunter and his wife to Karavasta and showed them

the ducks and waders at the one defended pond, the wife cried out with pride and happiness: "We didn't know we had birds like this here!" (Shortly after my visit, her husband sold his gun.)

Farther south, hope is harder to come by. As in Albania, history and politics in Egypt militate against conservation. The country is nominally a signatory to several international conventions regulating bird hunting, but long-standing resentment of European colonialism, compounded by the conflict between traditional Muslim culture and the destabilizing freedoms of the West, disincline the Egyptian government to abide by them. What's more, the Egyptian revolution of 2011 was specifically a repudiation of Egypt's police. The new president, Mohamed Morsi, could ill afford to enforce regulations overzealously; he had a lot more urgent worries than wildlife.

In northeastern Africa, unlike in the Balkans, there is also an ancient, rich, and continuous tradition of harvesting migratory birds of all sizes. (The miraculous provision of meat accompanying the manna from heaven that saved the Israelites in the Sinai is thought to have been migrating quail.) As long as the practice was pursued by traditional methods (handmade nets and lime sticks, small traps made of reeds, camels for transportation), the impact on Eurasian breeding bird populations was perhaps sustainable. The problem now is that new technology has vastly increased the harvest, while the tradition remains in place.

The most hope-confounding cultural disjunction, however, may be this: Egyptian bird hunters make no distinction between catching a fish and catching a bird (indeed, in the Nile Delta, they use the same nets for both), whereas, for many Westerners, birds have a charisma, and thus an emotional and even ethical status, that fish do not. In the desert west of Cairo, while sitting in a tent with six young Bedouin bird hunters, I saw



EGYPT

A tethered raptor serves as a trapper's spotter. When the bird spies a falcon, it looks up. This alerts the trapper to release a small bird wearing a snare, trapping the falcon if it comes in for the kill. Falconers pay up to \$35,000 for a live falcon.

a yellow wagtail hopping in the sand outside. My reaction was emotional: Here was a tiny, confident, warm-blooded, beautifully plumaged animal that had just flown several hundred miles across the desert. The reaction of the hunter next to me was to grab an air rifle and take a shot. For him, when the wagtail fluttered off unharmed, it was as if a fish had got away. For me it was a rare moment of relief.

The six Bedouin, barely out of their teens, were camped in a sparse grove of acacias, surrounded in all directions by sand roasting in September sun. They patrolled the grove with a shotgun and air rifles, stopping to flush birds from the acacias by clapping their hands and kicking sand. The grove was a magnet for south-bound migrants, and every bird that flew in,

regardless of its size or species or conservation status, was killed and eaten. For the young men, songbird hunting was a relief from boredom, an excuse to hang out as a group and do guy things. They also had a generator, a computer loaded with B movies, an SLR camera, night-vision goggles, and a Kalashnikov to fire for fun—they were all from well-to-do families.

Their morning's catch, strung on a wire like a large bunch of fish, included turtledoves, golden orioles, and tiny warblers. There's not much meat on a warbler, or even on an oriole, but to prepare for their long autumnal journey the migrants build up stores of fat, which could be seen in yellow lobes on their bellies when the hunters plucked them. Served with spiced rice, they made a rich lunch. Although orioles are



ALBANIA

A dead garganey floats among lifelike decoys that lured it within shooting range. Few citizens had guns until the national armories were ransacked in 1997. Now Albania is awash in firearms, and the coast has become lethal for migrating birds.

reputed in the Middle East to be good for male potency (they're "natural Viagra," I was told), I had no use for Viagra and helped myself only to a turtledove.

After lunch a hunter came into the tent with the yellow wagtail that I'd seen hopping on the sand. It looked even smaller dead than it had alive. "Poor thing," another hunter said, to general laughter. He was joking for a Westerner.

Because Egyptian desert travel is now by truck, rather than camel, practically every decent-size tree or bush, no matter how isolated, can be visited by hunters during the peak fall season. In some areas golden orioles are a cash crop, sold to middlemen for freezing and resale in the Persian Gulf states. The Bedouin, however, mostly eat what they catch or give it away to

friends and neighbors. At prime sites, such as the Al Maghrah oasis, where hunters congregate by the dozens, a single hunter can kill more than 50 orioles in one day.

I visited Al Maghrah late in the season, but the oriole decoys (consisting typically of a dead male on a stick) were still attracting good numbers, and the hunters rarely missed with their shotguns. Given how many hunters there were, it seemed quite possible that 5,000 orioles were being taken annually at this one location. And given that there are scores of other desert hunting sites, and that the bird is a prized quarry along the Egyptian coast as well, the losses in Egypt represent a significant fraction of the species' European population of two or three million breeding pairs. Enjoyment of a colorful

GARGANEY
Anas querquedula



Garganeys migrate through Albania, where populations are collapsing. The government has extended the hunting season so hunters won't have to settle for fewer kills.

species with a vast summer and winter range is thus being monopolized, every September, by a relatively tiny number of well-fed leisure hunters seeking natural Viagra. And while some of them may be using unlicensed weapons to kill orioles, the rest are breaking no Egyptian laws at all thereby.

At the oasis I also met a shepherd too poor to own a shotgun. He and his ten-year-old son instead relied on four nets, hung over trees, and they were mostly catching smaller birds like flycatchers, shrikes, and warblers. The son was therefore excited when he managed to corner a male oriole, splendidly gold and black, in a net. He came running back to his father with it—"An oriole!" he shouted proudly—and cut its throat with a knife. Moments later a female oriole flashed close to us, and I wondered if it might be the dead male's distraught mate. The shepherd boy chased it toward a netted palm tree, but the bird avoided the tree at the last second and headed into the open desert, flying southward.

Most of the Bedouin I spoke to told me that they won't kill resident species, such as hoopoes and laughing doves. Like other Mediterranean hunters, however, they consider all migratory species fair game; as the Albanians like to say, "They're not our birds." While every Egyptian hunter I met admitted that the number of migrants has been declining in recent years, only a few allowed that overharvesting might be a factor. Some hunters blame climate change; an especially popular theory is that the increasing number of electric lights at the coast is frightening the birds away. (In fact, lights are more likely to attract them.)

Environmental advocacy and education in Egypt are mostly confined to a few small non-governmental organizations, such as Nature Conservation Egypt (which provided assistance

with this story). European bird-advocacy groups expend significant money and manpower on Malta and in other European hot spots for migratory bird killing, but the problem in Egypt, which is more severe than anywhere in Europe, is largely overlooked. This represents, perhaps, the inverse of *They're not our birds: They're not our hunters*. But the political and cultural divide between the West and the Middle East is also daunting. The basic message of environmental "education" is, unavoidably, that Egyptians should stop doing what they've always done; and the concerns of a bird-smitten nation like England, whose colonization of Egypt is in any case still resented, seem as absurd and meddling as a Royal Society for the Protection of Catfish would seem to rural Mississippians.

Most Egyptian coastal towns have bird markets where a quail can be bought for two dollars, a turtledove for five, an oriole for three, and small birds for pennies. Outside one of these towns, El Daba, I toured the farm of a white-bearded man with a bird-trapping operation so large that, even after the families of his six sons had eaten their fill, he had a surplus to bring to market. Enormous nets were draped over eight tall tamarisk trees and many smaller bushes, encircling a grove of figs and olives; the nets were an inexpensive modern product, available in El Daba for only the past seven years. The sun was very hot, and migrant songbirds were arriving from the nearby coastline, seeking shelter. Repelled by the net on one tree, they simply flew to the next tree, until they found themselves caught. The farmer's grandsons ran inside the nets and grabbed them, and one of his sons tore off their flight feathers and dropped them in a plastic grain sack. In 20 minutes I saw a red-backed shrike, a collared flycatcher, a spotted flycatcher, a male golden oriole, a chiffchaff, a blackcap, two wood warblers, two cisticolas,

A photograph showing a person in a dark jacket and red shoes climbing a wooden ladder into a dense grove of trees. The trees are covered in green leaves and clusters of small, round, yellow fruit. The scene is set outdoors, with sunlight filtering through the branches.

CYPRUS

Volunteers with the Committee Against Bird Slaughter sneak into a grove where a farmer has just placed lime sticks to snag unwary birds. The organization dismantled nearly 9,000 traps on Cyprus last year.



CYPRUS

After prying this blackcap from a lime stick, the songbird's rescuer uses his saliva to remove sticky plum tree sap from its feathers and feet so that it can safely fly when released.





BLACKCAP
Sylvia atricapilla



In recent decades some Eurasian blackcaps have taken to migrating north to the British Isles in winter to take advantage of well-stocked bird feeders.

and many unidentified birds disappear into the sack. By the time we paused in the shade, amid the discarded heads and feathers of cuckoos and hoopoes and a sparrow hawk, the sack was bulging, the oriole crying out inside it.

Based on the farmer's estimates of his daily take, I calculated that every year between August 25 and September 25, his operation removes 600 orioles, 250 turtledoves, 200 hoopoes, and 4,500 smaller birds from the air. The supplemental income is surely welcome, but the farm would clearly have thrived without it; the furnishings in the family's spacious guest parlor, where I was treated with great Bedouin hospitality, were brand-new and of high quality.

Everywhere I went along the coast, from Marsa Matruh to Ras el Barr, I saw nets like the farmer's. Even more impressive were the mist nets used for catching quail: ultrafine nylon netting, all but invisible to birds, that is strung on poles and reaches from ground level to 11 or more feet off the ground. The mist nets, too, are a recent innovation, having been introduced in Sinai about 15 years ago and spread westward until they now cover the entire Egyptian Mediterranean coast. In north Sinai alone, mist nets stretch for 50 miles. Along the coastal highway west of Sinai, the nets run to the horizon and pass straight through tourist towns, in front of hotels and condominiums.

Much of Egypt's coast is, on paper, protected. But the coastal preserves protect birds only to the extent of requiring permits to erect nets for catching them. These permits are cheap and freely granted; official restrictions on the height and spacing of the nets are honored in the breach. The owners of the nets go out before dawn and wait for quail, arriving from across the sea, to come zinging over the beach and enmesh themselves. On a good day, a third of a mile of nets can yield 50 quail or more. My very low-end

estimate, based on figures from a bad year, is that 100,000 quail are taken annually in Egypt's coastal mist nets alone.

Even as quail are becoming very difficult to find in much of Europe, the take in Egypt is increasing, due to the burgeoning use of playback technology. The best system, Bird Sound, whose digital chip holds high-quality recordings of a hundred different bird sounds, is illegal to use for hunting purposes in the EU but is nevertheless sold in stores with no questions asked. In Alexandria, I spoke with a sport hunter, Wael Karawia, who claimed to have introduced Bird Sound to Egypt in 2009. Karawia said he now feels "very bad, very regretful" about it. Normally, perhaps three-quarters of incoming quail fly over the mist nets, but hunters using Bird Sound can attract the higher flying ones as well; already all the mist netters in north Sinai are doing it, some of them in spring as well as fall. Hunters on Egypt's large lakes have also begun to use Bird Sound to capture entire flocks of ducks at night.

"It will start to affect the birds, it has to," Karawia told me. "The problem is the mentality—people want to fish anything and hunt anything, with no rules. We already had a lot of guns before the revolution, and since then there's been a 40 percent increase. The people who don't have money make their own guns, which is very dangerous—it could get them three years in jail—but they don't care. Even the kids are doing it. School starts in September, but the kids don't start until the hunting season ends."

On the beach in the tourist town of Baltim, I had an encounter with some of these kids. Quail are the only permissible target of mist netters, but there is always a bycatch of small birds and even of the falcons that prey on them. At sundown in Baltim, walking with a guide from Nature Conservation Egypt and an official from



ITALY

Two forest rangers, members of a special police unit devoted to poaching, question a couple after they saw the man, at far right, carrying a shotgun near an illegal net in Brescia. Last fall the police caught 43 people in one antipoaching operation.

the local protected area, I noticed a beautiful and tiny shorebird, a little ringed plover, caught in a net in the shadow of condominiums. My guide, Wael Shohdi, began to extricate it delicately but stopped when a young man came running up, carrying a mesh bag and trailed by two teenage friends. “Don’t touch the bird,” he shouted angrily. “Those are our nets!”

“It’s OK,” Shohdi assured him. “We handle birds all the time.”

A tussle ensued as the young hunter tried to show Shohdi how to yank the bird out without damaging the net. Shohdi, whose priority was the safety of the bird, somehow managed to free the plover in one piece. But the hunter then demanded that Shohdi hand it over.

The government official, Hani Mansour

Bishara, pointed out that, along with two live quail, the hunter had a live songbird in his bag.

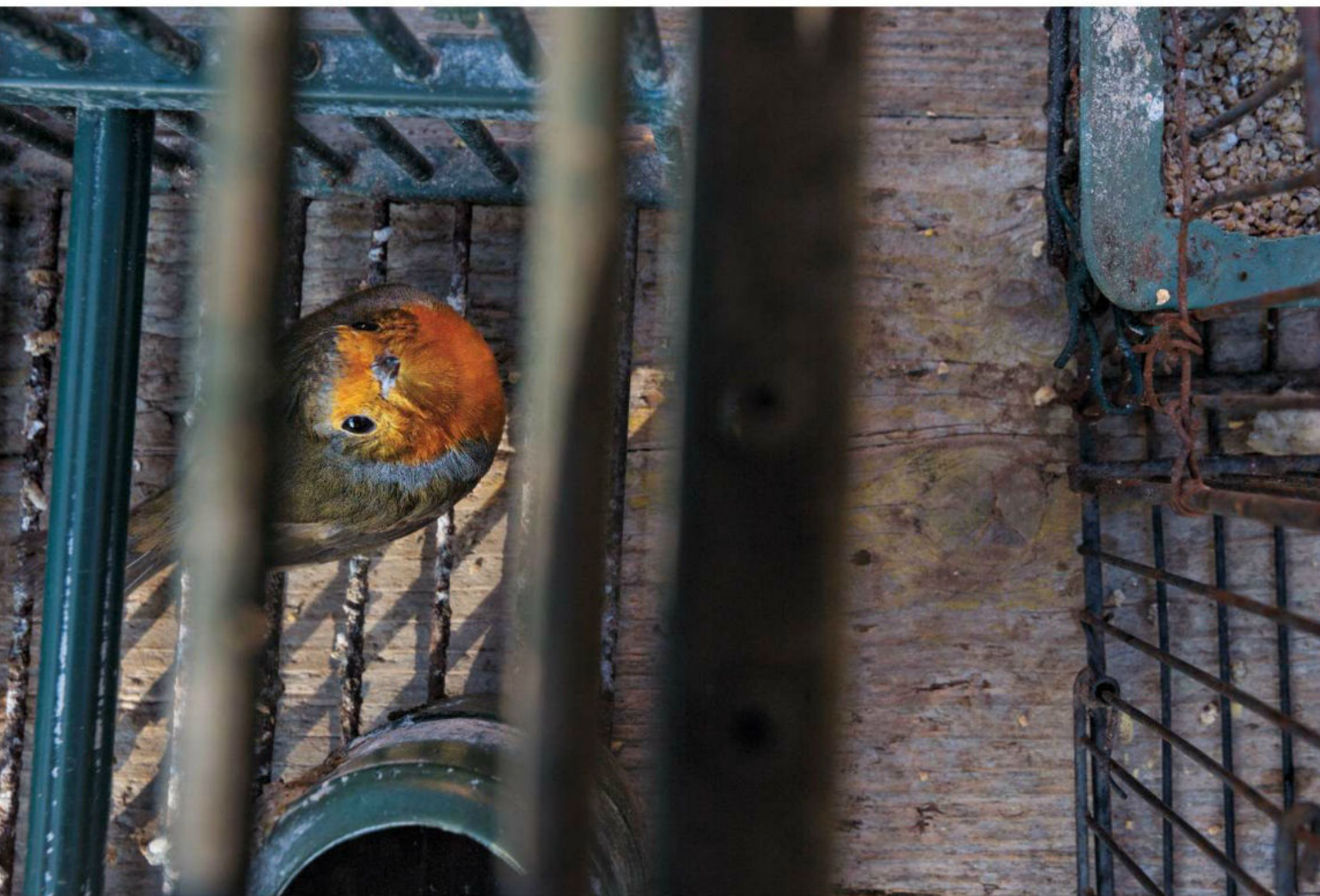
“No, that’s a quail,” the hunter said.

“No, it’s not.”

“OK, it’s a wheatear. But I’m 20 years old and we’re living from this net.”

Not being an Arab speaker, I learned only afterward what they were saying. What I could see in the moment was Shohdi continuing to hold the plover in his hand while the hunter reached for it angrily, trying to grab it away. We were in a country where millions of birds were being killed, but I couldn’t help worrying about this individual plover’s fate. I urged Shohdi to remind the hunter that it was illegal to keep anything but quail from the nets.

Shohdi did this, but the law was apparently



ITALY

Confiscated from a poacher in Brescia, this robin will be released to fly away into an uncertain world, where habitat is threatened and predators and poachers await. The survival of songbirds depends in part upon eliminating illegal hunting.

not a good argument to use on angry 20-year-olds. Instead, with a view to changing hearts and minds, Shohdi and Bishara made the case that the little ringed plover is an important species, found only on mudflats, and that, moreover, it might be carrying a dangerous disease. (“We were lying a little bit,” Shohdi told me later.)

“So which is it?” the hunter demanded. “A diseased bird or an important species?”

“Both!” Shohdi and Bishara said.

“If it’s true about the disease,” one of the teenagers said, “we all would have been dead years ago. We eat everything from the nets. We never let anything go.”

“You can still get the disease from cooked birds,” Bishara improvised.

My concern about the plover deepened when

Shohdi handed it over to the hunter, who (as I learned only subsequently) had sworn by Allah that he would release both it and the wheatear, just not while we were watching.

“But the *National Geographic* needs to see that they really are released,” Shohdi said.

Becoming even angrier, the hunter took out the wheatear and flung it in the air, and then did the same with the plover. Both flew straight to some of their fellows, farther down the beach, without looking back. “I only did it,” the hunter said defiantly, “because I’m a man of my word.” There wasn’t much more than one large bite of meat on the two birds put together, but I could see, in the hunter’s bitter expression, how much it cost him to let them go. He wanted to keep them even more than I wanted to see them freed.

EUROPEAN ROBIN
Erithacus rubecula



The European robin shares an orange breast with its American counterpart, but not much else. It weighs one-fifth as much and is classed in a different bird family.

Before leaving Egypt, I spent some days with Bedouin falcon trappers in the desert. Even by Bedouin standards, falcon trapping is a pursuit for men with a lot of time on their hands. Some have been doing it for 20 years without catching either of the two prized species, saker falcons and peregrine falcons, that are prized by middlemen catering to ultra-wealthy Arab falconers. The saker is so rare that not more than a dozen or two are captured in any given year, but the size of the jackpot (a good saker can fetch over \$35,000, a peregrine over \$15,000) entices hundreds of hunters into the desert for weeks at a time.

Falcon trapping requires the cruel use of many smaller birds. Pigeons are tied to stakes in the sand and left in the sun to attract raptors; doves and quail are outfitted with harnesses bristling with small nylon nooses in which sakers and peregrines can get their feet stuck; and smaller falcons, such as lanners or kestrels, have their eyelids sewn shut and a weighted, noose-laden decoy attached to one leg. Hunters drive around the desert in their Toyota pickups, visiting the staked pigeons and stopping to hurl the disabled kestrels into the air like footballs, in the hope of attracting a saker or a peregrine—a blinded, weighted kestrel can't fly far. The hunters also often tether an unblinded falcon to the hood of their trucks and keep an eye on it while they speed through the sand. When the falcon looks up, it means that a larger raptor is overhead, and the hunters leap out to deploy their various decoys. The same routine is followed every afternoon, week after week.

One of the two most heartening things I witnessed in Egypt was the rapt attention that falcon hunters gave to my paperback field guide, *Birds of Europe*. They invariably clustered around it and turned its pages slowly, back to front, studying the illustrations of birds they'd

seen and birds they hadn't. One afternoon, while watching some of them do this, in a tent where I was offered strong tea and a very late lunch, I was stabbed with the crazy hope that the Bedouin were all, without yet realizing it, passionate bird-watchers.

Before we humans could be served lunch, one of the hunters tried to feed headless warblers to the blinded kestrel and the blinded sparrow hawk that were in the tent with us. The kestrel ate readily, but no amount of pushing the meat into the sparrow hawk's face would induce it to eat. Instead, it busied itself with pecking at the twine that bound its leg—futilely, it seemed to me, at least until after lunch, when I was outside the tent and letting the hunters try out my binoculars. All of a sudden a shout went up. I turned and saw the sparrow hawk winging purposefully away from the tent and into the desert.

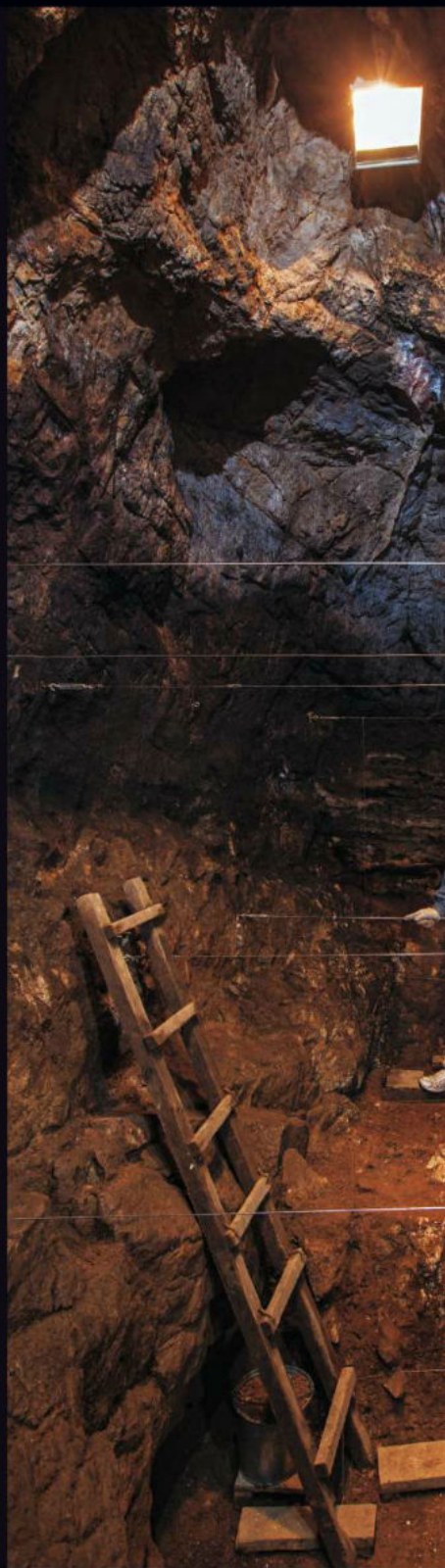
The hunters immediately gave chase in their trucks, in part because the bird was valuable to them but also in part—and this was the other heartening thing I witnessed—because a blinded bird couldn't survive on its own, and they felt bad for it. (At the end of the falcon season, hunters unsuture the eyelids of their decoy falcons and release them, if only because it's a bother to feed the birds year-round.) The hunters drove farther and farther into the desert, worrying about the sparrow hawk, hoping to spot it, but I personally had mixed feelings. I knew that if it got away, and if no other group of hunters happened upon it, it would soon be dead; but in its yearning to escape captivity, even blinded, even at the cost of certain death, it seemed to embody the essence of wild birds and why they matter. Twenty minutes later, when the last of the hunters returned to the tent empty-handed, my thought was: At least this bird had a chance to die free. □

THE CASE OF THE MISSING ANCESTOR

DNA FROM A CAVE IN RUSSIA ADDS A MYSTERIOUS NEW MEMBER TO THE HUMAN FAMILY.

THE TOOTH

Two molars, including this one, and a chip from a pinkie bone are the only fossil evidence so far of the enigmatic people known as the Denisovans.





THE CAVE

All three fossils were found in Denisova cave in southern Siberia, where Russian student Zoya Gudkova takes a break from digging. Neanderthals and modern humans also lived there tens of thousands of years ago.



THE THEORY

The Denisovans' closest cousins were Neanderthals (below). After leaving Africa, modern humans interbred with both these ancient forms of human. The evidence comes from their DNA and ours.

SKULL PHOTOGRAPHED WITH SUPPORT FROM ALAIN FROMENT, MUSEUM NATIONAL D'HISTOIRE NATURELLE, PARIS



THE DNA

Genetic material from ancient bone, like that in the vial above, can reveal much about the history of an ancient population, even when few fossils exist—as in the case of the Denisovans.



THE EXPERT

Svante Pääbo led the team that studied the Denisovans' DNA. His ultimate quarry, he says, is not them but us: He wants to understand the genetic changes that made humans modern.



BY JAMIE SHREEVE · PHOTOGRAPHS BY ROBERT CLARK

In the Altay Mountains of southern Siberia, some 200 miles from where Russia touches Mongolia, China, and Kazakhstan, nestled under a rock face about 30 yards above a little river called the Anuy, there is a cave called Denisova. It has long attracted visitors. The name comes from that of a hermit, Denis, who is said to have lived there in the 18th century.

Long before that, Neolithic and later Turkic pastoralists took shelter in the cave, gathering their herds around them to ride out the Siberian winters. Thanks to them, the archaeologists who work in Denisova today, surrounded by walls spattered with recent graffiti, had to dig through deep layers of goat dung to get to the deposits that interested them. But the cave's main chamber has a high, arched ceiling with a hole near the top that directs shimmering shafts of sunlight into the interior, so that the space feels holy, like a church.

In the back of the cave is a small side chamber, and it was there that a young Russian archaeologist named Alexander Tsybankov was digging one day in July 2008, in deposits believed to be 30,000 to 50,000 years old, when he came upon a tiny piece of bone. It was hardly promising: a rough nubbin about the size and shape of a pebble you might shake out of your shoe. Later, after news of the place had spread, a paleoanthropologist I met at Denisova described the bone to me as the "most unspectacular fossil I've ever seen. It's practically depressing." Still, it was a bone. Tsybankov bagged it and put it in his pocket to show a paleontologist back at camp.

The bone preserved just enough anatomy for the paleontologist to identify it as a chip from a primate fingertip—specifically the part that faces the last joint in the pinkie. Since there is no evidence for primates other than humans in

Siberia 30,000 to 50,000 years ago—no apes or monkeys—the fossil was presumably from some kind of human. Judging by the incompletely fused joint surface, the human in question had died young, perhaps as young as eight years old.

Anatoly Derevianko, leader of the Altay excavations and director of the Institute of Archaeology and Ethnography in Novosibirsk, thought the bone might belong to a member of our own species, *Homo sapiens*. Sophisticated artifacts that could only be the work of modern humans, including a beautiful bracelet of polished green stone, had previously been found in the same deposits. But DNA from a fossil found earlier in a nearby cave had proved to be Neanderthal, so it was possible this bone was Neanderthal as well.

Derevianko decided to cut the bone in two. He sent one half to a genetics laboratory in California; so far he has not heard from that half again. He slipped the other half into an envelope and had it hand-delivered to Svante Pääbo, an evolutionary geneticist at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. It was there that the case of the Denisovan pinkie bone took a startling turn.

Pääbo, a transplanted Swede, is arguably the world's leading expert in ancient DNA, especially human DNA. His milestones are many. In 1984 he became the first person to isolate DNA from an Egyptian mummy. In 1997 he accomplished

THE BRACELET WAS MODERN HUMAN. THE TOE WAS

the same feat for the first time with a Neanderthal, a kind of human that vanished more than 25,000 years before the Egyptian pharaohs. That secured his scientific reputation.

When Pääbo received the package from Derevianko, his team was hard at work producing the first sequence of the entire Neanderthal genome—another feat that had once seemed impossible and that was occupying most of his attention. His lab also had a backlog of other fossils to test from all parts of the globe. So it wasn't until late 2009 that the little Russian finger bone drew the attention of Johannes Krause, at the time a senior member of Pääbo's team. (He's now at the University of Tübingen.) Like everyone else, Krause assumed the bone was from an early modern human. He had developed a method for distinguishing the DNA of such a fossil from that of the archaeologists, museum workers, and anyone else who might have handled and therefore contaminated it.

Krause and his student Qiaomei Fu extracted the finger bone's mitochondrial DNA (mtDNA), a small bit of the genome that living cells have hundreds of copies of and that is therefore easier to find in ancient bone. They compared the DNA sequence with those of living humans and Neanderthals. Then they repeated the analysis, because they couldn't believe the results they'd gotten the first time around.

On a Friday afternoon, with Pääbo away at a meeting at Cold Spring Harbor Laboratory on Long Island, Krause called a meeting of the lab staff and challenged anyone to come up with a different explanation for what he was seeing. No one could. Then he dialed Pääbo's cell. "Johannes asked me if I was sitting down," Pääbo remembers. "I said I wasn't, and he replied that I had better find a chair."

Krause himself recalls that Friday as "scientifically the most exciting day of my life." The tiny chip of a finger bone, it seemed, was not from a modern human at all. But it wasn't from

a Neanderthal either. It belonged to a new kind of human being, never before seen.

IN JULY 2011, three years after Tsybankov unearthed the bone chip, Anatoly Derevianko organized a scientific symposium at the archaeological camp a few hundred yards from Denisova cave. At an opening night dinner punctuated with frequent toasts of vodka, Derevianko welcomed the 50 researchers, including Pääbo, who had come to see the cave and share their views on how the mysterious new human fit into the fossil and archaeological record for human evolution in Asia.

The year before, two other fossils had been found to contain DNA similar to that of the finger bone, both of them molars. The first tooth had turned up among the specimens from Denisova housed at Derevianko's institute in Novosibirsk. It was bigger than either a modern human or a Neanderthal tooth, in size and shape resembling the teeth of much more primitive members of the genus *Homo* who lived in Africa millions of years ago. The second molar had been found in 2010 in the same cave chamber that had yielded the finger bone—indeed, near the bottom of the same 30,000-to-50,000-year-old deposits, called Layer 11.

Remarkably, that tooth was even bigger than the first, with a chewing surface twice that of a typical human molar. It was so large that Max Planck paleoanthropologist Bence Viola mistook it for a cave bear tooth. Only when its DNA was tested was it confirmed to be human—specifically, Denisovan, as the scientists had taken to calling the new ancestors. "It shows you how weird these guys are," Viola told me at the symposium. "At least their teeth are just very strange."

Pääbo's team could extract only a tiny amount of DNA from the teeth—just enough to prove they came from the same population as the finger, though not from the same individual. But the finger bone had been spectacularly generous.

DNA degrades over time, so usually very little remains in a bone tens of thousands of years old. Moreover, the DNA from the bone itself—called endogenous DNA—is typically just a tiny fraction

Jamie Shreeve, executive editor for science, has written two books on human origins. This is Robert Clark's 31st story for National Geographic.

NEANDERTHAL. THE PINKIE WAS SOMETHING ELSE.

of the total DNA in a specimen, most of which comes from soil bacteria and other contaminants. None of the Neanderthal fossils Pääbo and his colleagues had ever tested contained even 5 percent endogenous DNA, and most had less than one percent. To their amazement, the DNA in the finger bone was some 70 percent endogenous. Apparently, the cold cave had preserved it well.

Given so much DNA, the scientists easily ascertained that there was no sign of a male Y chromosome in the specimen. The fingertip had belonged to a little girl who had died in or near Denisova cave tens of thousands of years before. The scientists had no idea, at first, what she looked like—just that she was radically different from anything else they had ever seen.

For a while they thought they might have her toe too. In the summer of 2010 a human toe bone had emerged, along with the enormous tooth, from Layer 11. In Leipzig a graduate student named Susanna Sawyer analyzed its DNA. At the symposium in 2011 she presented her results for the first time. To everyone's shock, the toe bone had turned out to be Neanderthal, deepening the mystery of the place.

The green stone bracelet found earlier in Layer 11 had almost surely been made by modern humans. The toe bone was Neanderthal. And the finger bone was something else entirely. One cave, three kinds of human being. "Denisova is magical," said Pääbo. "It's the one spot on Earth that we know of where Neanderthals, Denisovans, and modern humans all lived." All week, during breaks in the conference, he kept returning alone to the cave. It was as if he thought he might find clues by standing where the little girl may have stood and touching the cool stone walls she too may have touched.

PÄÄBO GREW UP in Stockholm with his single mother, a chemist, and on certain days with his father, a biochemist named Sune Bergström, who had another, legitimate family and would later win a Nobel Prize. Pääbo's own first passion was Egyptology, but he switched to molecular biology, then fused the two interests in 1984 with his

work on mummy DNA. Once anchored in the study of the past, he never let go. He is 58 now, tall and lanky, with large ears, a long, narrow head, and pronounced eyebrows that arch up and down animatedly when he's excited—about Denisova, for instance.

How had all three kinds of human ended up there? How were Neanderthals and Denisovans related to each other and to the sole kind of human that inhabits the planet today? Did their ancestors have sex with ours? Pääbo had a history with that kind of question.

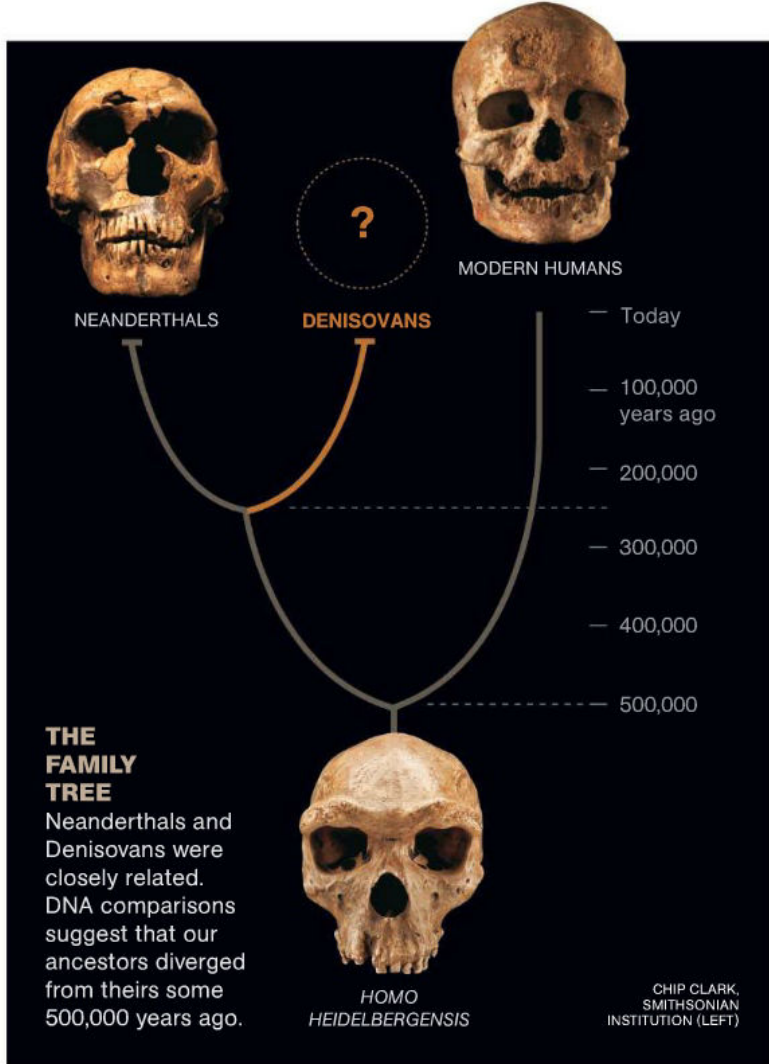
The Neanderthal DNA he had made headlines with in 1997 was utterly different from that of any person now alive on Earth. It seemed to suggest that Neanderthals had been a separate species from us that had gone extinct—suspiciously soon after our ancestors first migrated out of Africa into the Neanderthals' range in western Asia and Europe. But that DNA, like Krause's first extract from the Denisovan finger, was mtDNA: It came from the mitochondria, the energy-producing organelles inside the cell, and not from the cell nucleus, where the vast bulk of our genome resides. Mitochondrial DNA includes only 37 genes, and it's inherited only from the mother. It's a limited record of a population's history, like a single page torn from a book.

By the time of the Denisova symposium, Pääbo and his colleagues had published first drafts of the entire Neanderthal and Denisovan genomes. Reading so many more pages allowed Pääbo and his colleagues, including David Reich at Harvard University and Montgomery Slatkin at the University of California, Berkeley, to discover that human genomes today actually contain a small but significant amount of Neanderthal code—on average about 2.5 percent. The Neanderthals still may have been swept into extinction by the strange, high-browed new people who followed them out of Africa, but not before some commingling that left a little Neanderthal in most of us, 50,000 years later. Only one group of modern humans escaped that influence: Africans, because the commingling happened outside that continent.

Although the Denisovans' genome showed

A TALE OF THREE HUMANS

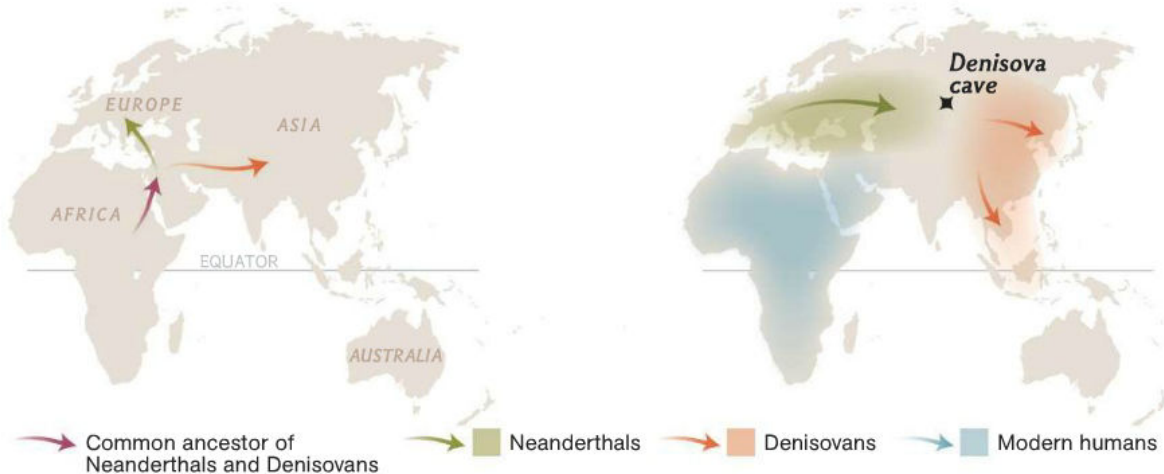
A third kind of human, called Denisovans, seems to have coexisted in Asia with Neanderthals and early modern humans. The latter two are known from abundant fossils and artifacts. Denisovans are defined so far only by the DNA from one bone chip and two teeth—but it reveals a new twist to the human story.



THE JOURNEY

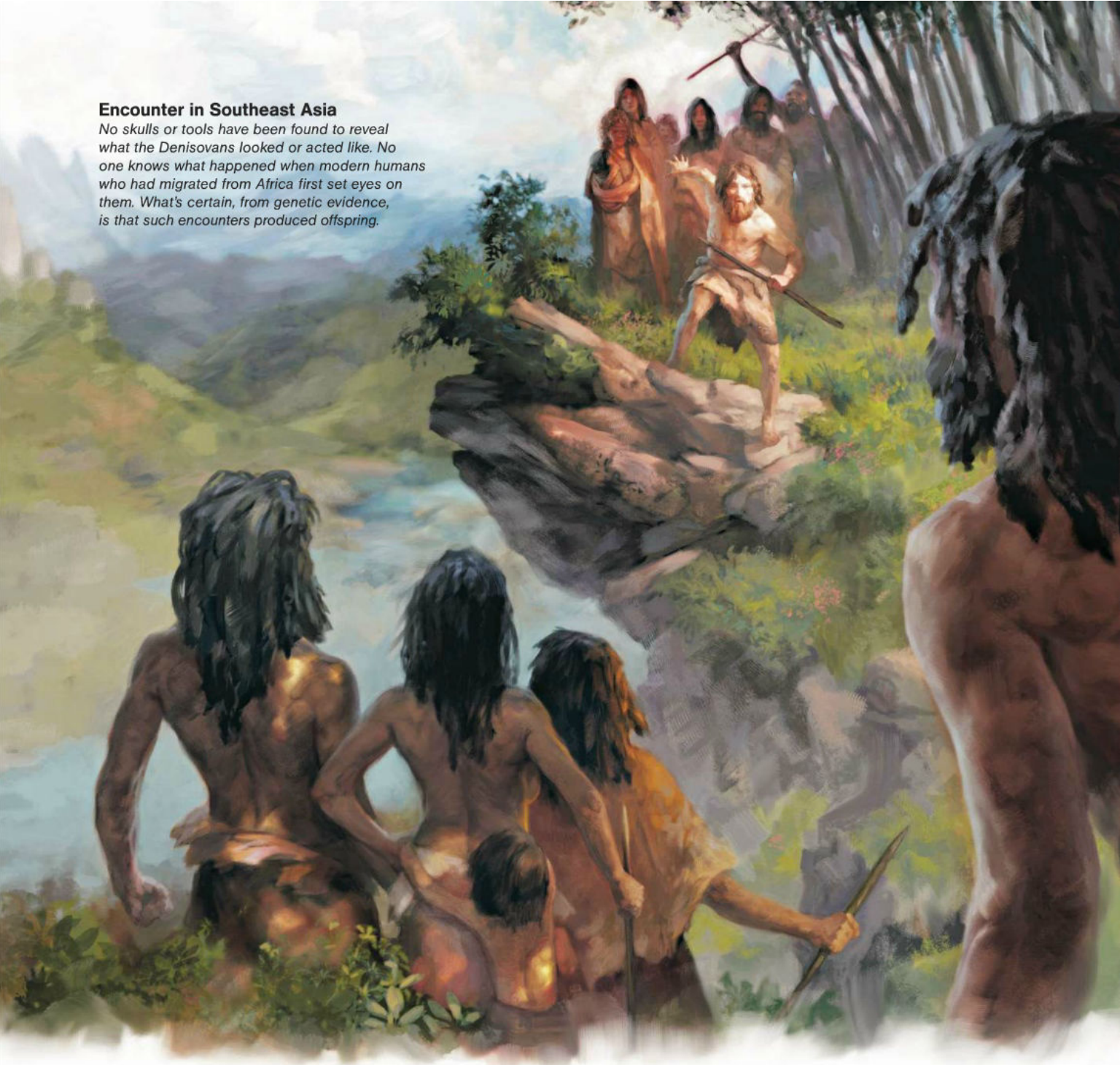
500,000-250,000 years ago After the common ancestor of Neanderthals and Denisovans left Africa, the population split. Neanderthals spread into Europe, Denisovans into Asia.

100,000-60,000 years ago The Neanderthals' range expanded east to overlap with the Denisovans'; evidence of both kinds of human has been found in Denisova cave in Siberia.

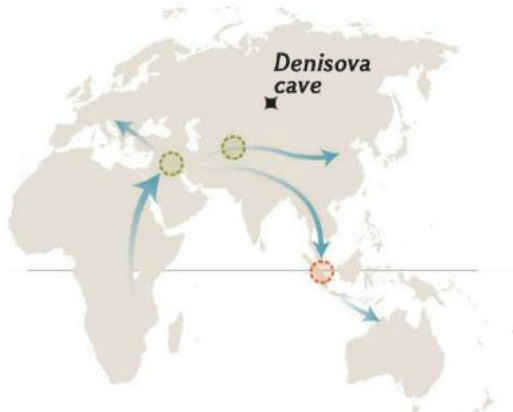


Encounter in Southeast Asia

No skulls or tools have been found to reveal what the Denisovans looked or acted like. No one knows what happened when modern humans who had migrated from Africa first set eyes on them. What's certain, from genetic evidence, is that such encounters produced offspring.



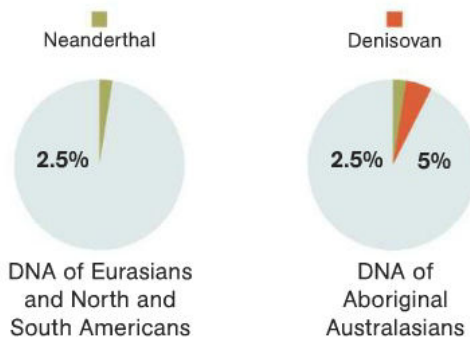
70,000-40,000 years ago After migrating out of Africa, modern humans met Neanderthals in the Middle East and later the Denisovans in Southeast Asia.



Region of interbreeding
 ● With Neanderthals ● With Denisovans

THE LEGACY

Today traces of Neanderthal DNA in all non-Africans and of Denisovan DNA in Aboriginal Australasians show that our ancestors mated with both kinds of vanished human.



JUAN VELASCO AND MAGGIE SMITH, NGM STAFF
 ART: JON FOSTER. SOURCES: SVANTE PÄÄBO AND BENCE VIOLA, MAX PLANCK INSTITUTE FOR EVOLUTIONARY ANTHROPOLOGY; CHRIS STRINGER, NATURAL HISTORY MUSEUM OF LONDON; OFER BAR-YOSEF, HARVARD UNIVERSITY

WHY HAD THEY LEFT NO CLEAR ARCHAEOLOGICAL

that they were more closely related to the Neanderthals, they too had left their mark on us. But the geographic pattern of that legacy was odd. When the researchers compared the Denisovan genome with those of various modern human populations, they found no trace of it in Russia or nearby China, or anywhere else, for that matter—except in the genomes of New Guineans, other people from islands in Melanesia, and Australian Aborigines. On average their genomes are about 5 percent Denisovan. Negritos in the Philippines have as much as 2.5 percent.

Putting all the data together, Pääbo and his colleagues came up with a scenario to explain what might have occurred. Sometime before 500,000 years ago, probably in Africa, the ancestors of modern humans split off from the lineage that would give rise to Neanderthals and Denisovans. (The most likely progenitor of all three types was a species called *Homo heidelbergensis*.) While our ancestors stayed in Africa, the common ancestor of Neanderthals and Denisovans migrated out. Those two lineages later diverged, with the Neanderthals initially moving west into Europe and the Denisovans spreading east, perhaps eventually populating large parts of the Asian continent.

Later still, when modern humans ventured out of Africa themselves, they encountered Neanderthals in the Middle East and Central Asia, and to a limited extent interbred with them. According to evidence presented by David Reich at the Denisova symposium, this mixing most likely occurred between 67,000 and 46,000 years ago. One population of modern humans then continued east into Southeast Asia, where, sometime around 40,000 years ago, they encountered Denisovans. The moderns interbred with them as well and then moved into Australasia, carrying Denisovan DNA.

This scenario might explain why the only evidence so far that the Denisovans even existed is three fossils from a cave in Siberia and a 5 percent stake in the genomes of people living today thousands of miles to the southeast. But it left a lot of questions unanswered. If the Denisovans were so widespread, why was there no

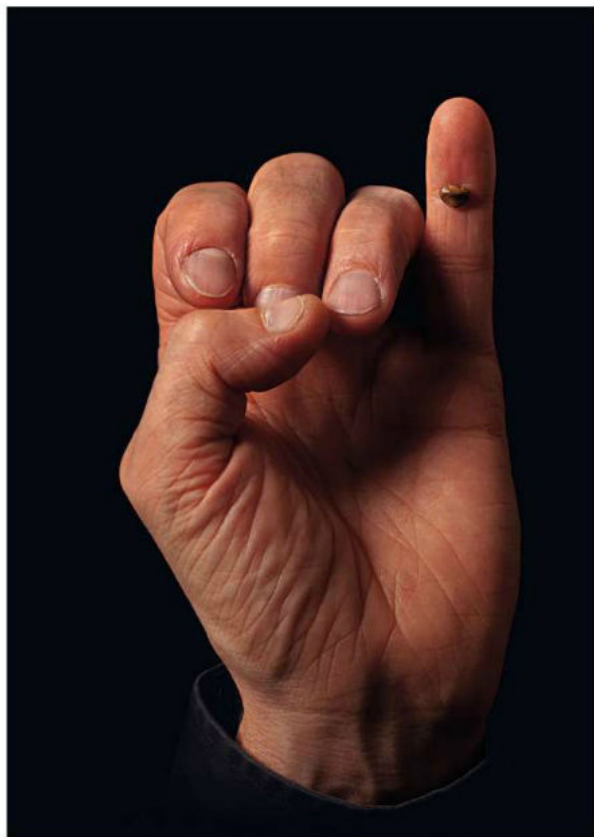
trace of them in the genomes of Han Chinese or of any other Asian people between Siberia and Melanesia? Why had they left no mark in the archaeological record—no distinctive tools, say? Who were they really? What did they look like? “Clearly we need much more work,” Pääbo acknowledged at the Denisova symposium.

The best of all possible developments would be to find Denisovan DNA in a skull or other fossil with distinctive morphological features, one that could serve as a Rosetta stone for re-examining the whole fossil record of Asia. There are some intriguing candidates, most from China, and three skulls in particular, dated between 250,000 and 100,000 years ago. Pääbo is working closely with scientists at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing and has set up a DNA testing lab there. Unfortunately DNA does not preserve well in warmer climates. To date, no other fossil has been identified as Denisovan by the only way Denisovans can be known: their DNA.

IN 2012 PÄÄBO’S GROUP published a new version of the finger bone’s genome—astonishingly, one that in accuracy and completeness rivals any living human’s genome that has been sequenced. The breakthrough came from a German postdoc in Pääbo’s lab named Matthias Meyer. DNA consists of two interlocking strands—the familiar double helix. Previous methods for retrieving DNA from fossil bone could read out sequences only when both strands were preserved. Meyer had developed a technique for recovering short, single-stranded fragments of DNA as well, greatly increasing the amount of raw material to work with. The method produced a version of the Denisovan girl’s genome so precise that the team could discriminate between genetic information inherited from her mother and that from her father. In effect, they now had two highly accurate Denisovan genomes, one from each parent. These in turn opened a window on the entire history of their population.

One immediate revelation was how little variation there was between the parents’ genomes—

RECORD? WHO WERE THE DENISOVANS REALLY?



THE BONE A replica shows the size and position—on Pääbo’s pinkie—of the bone chip that allowed his lab to discover the Denisovans through their DNA. The chip belonged to an eight-year-old girl.

about a third as much as there is between any two living humans. The differences were sprinkled across the genomes, which ruled out inbreeding: If the girl’s parents had simply been closely related, they would have had huge chunks of exactly matched DNA. The pattern indicated instead that the Denisovan population represented by the fossil had never been large enough to have developed much genetic diversity. Worse, it seemed to have suffered a drastic decline sometime before 125,000 years ago—the little girl in the cave may have been among the last of her kind.

Meanwhile the ancestral population of modern humans was expanding. Myriad fossils, libraries full of books, and the DNA of seven billion people are available to document our subsequent population history. Pääbo’s team

discovered a completely different one inside a single bone chip. The thought tickles him. “It’s incredibly cool that there is no one walking around today with a population history like that,” Pääbo told me, his eyebrows shooting up.

And yet the Denisovans also have something to say about our own kind. With virtually every letter of the Denisovan genetic code in hand, Pääbo and his colleagues were able to take aim at one of the profoundest mysteries: In our own genomes, what is it that makes us us? What defining changes in the genetic code took place after we separated from our most recent ancestor? Looking at the places where all living humans share a novel genetic signature but the Denisovan genome retains a primitive, more apelike pattern, the researchers came up with a surprisingly short list. Pääbo has called it the “genetic recipe for being a modern human.” The list includes just 25 changes that would alter the function of a particular protein.

Intriguingly, five of these proteins are known to affect brain function and development of the nervous system. Among them are two genes where mutations have been implicated in autism and another that’s involved in language and speech. Just what those genes actually do to make us think, act, or talk differently than Denisovans, or any other creature that has walked the Earth, remains to be seen. The lasting contribution of studying Denisovan DNA, Pääbo says, “will be in finding what is exclusively human.”

But what of the little girl herself? The tiny bit of bone that is all we ever had of her—or at least the half that went to Leipzig—is gone now. In pulling DNA from it, Johannes Krause and Qiaomei Fu eventually used it all up. The little girl has been reduced to a “library” of DNA fragments that can be exactly copied again and again forever. In the scientific paper discussing the history of her population, Pääbo and his colleagues did mention, almost in passing, a few facts about her that they had gleaned from that library: She probably had dark hair, dark eyes, and dark skin. It isn’t much, but at least it sketches in broad strokes what she looked like. Just so we know whom to thank. □

Genes Are Us. And Them.

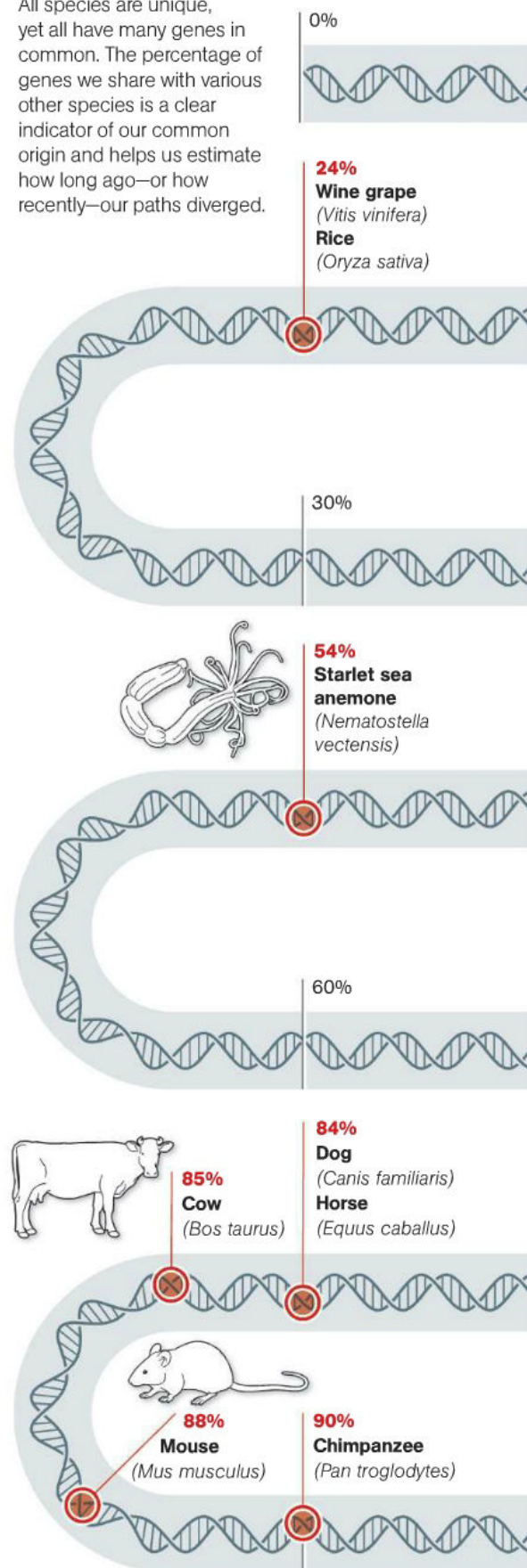
A HUMAN and a grain of rice may not, at first glance, look like cousins. And yet we share a quarter of our genes with that fine plant. The genes we share with rice—or rhinos or reef coral—are among the most striking signs of our common heritage. All animals, plants, and fungi share an ancestor that lived about 1.6 billion years ago. Every lineage that descended from that progenitor retains parts of its original genome, embodying one of evolution's key principles: If it's not broke, don't fix it. Since evolution has conserved so many genes, exploring the genomes of other species can shed light on genes involved in human biology and disease. Even yeast has something to tell us about ourselves.

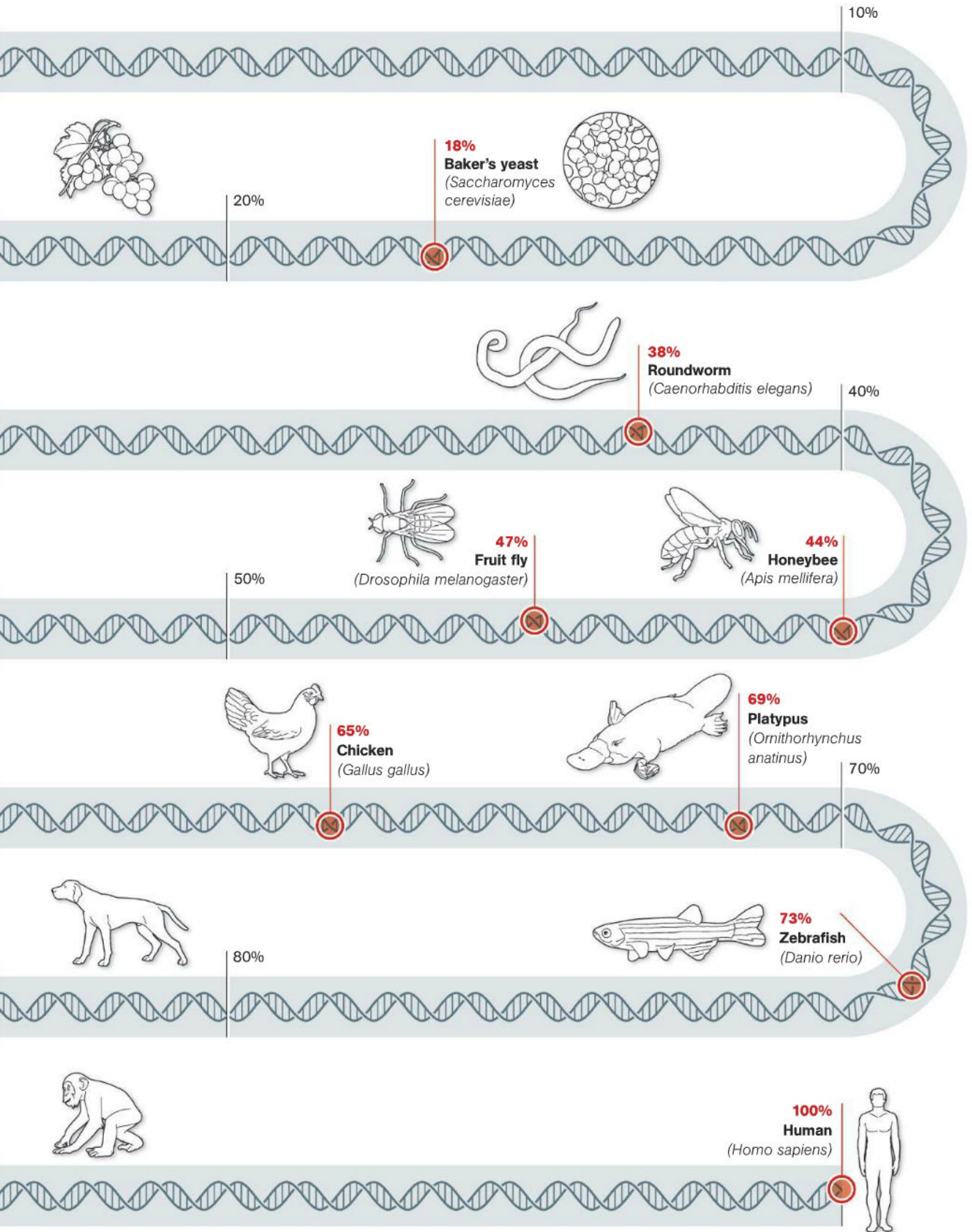
Of course, we aren't really much like yeast at all. The genes we still share we use differently, in the same way you can use a clarinet to play the music of Mozart or Benny Goodman. And our catalogs of genes themselves have changed. Genes can disappear, and new ones can arise from mutations in DNA that previously served some other function or no function at all. Other novel genes have been delivered into our genomes by invading viruses. It's hardly surprising that we share many more genes with chimpanzees than with yeast, because we've shared most of our evolutionary journey with those apes. And in the small portion of our genes with no counterpart in chimpanzees, we may be able to find additional clues to what makes us uniquely human.

—Carl Zimmer

SHARED LEGACY

All species are unique, yet all have many genes in common. The percentage of genes we share with various other species is a clear indicator of our common origin and helps us estimate how long ago—or how recently—our paths diverged.





By Michael Finkel Photograph by Marco Grob

Bat Man

What **DANIEL KISH** does, astonishingly, elegantly, makes you wonder how much untapped potential lies within the human body. Kish was born with retinal cancer, and to save his life, both eyes were removed by the time he was 13 months old. He soon started making a clicking noise with his tongue. It seemed to help him get around. Now 47, he navigates primarily using echolocation. Yes, like a bat. He's so good, he can ride a bicycle in traffic. His group, World Access for the Blind, teaches others the art of the click.

How does human echolocation work?

Sound waves are produced by every tongue click. These waves bounce off surfaces all around and return to my ears as faint echoes. My brain processes the echoes into dynamic images. It's like having a conversation with the environment.

What do you see in your mind's eye as you click?

Each click is like a dim camera flash. I construct a three-dimensional image of my surroundings for hundreds of feet in every direction. Up close, I can detect a pole an inch thick. At 15 feet, I recognize cars and bushes. Houses come into focus at 150 feet.

But you still use a long white cane.

I have difficulty detecting small items at low level or places where the ground drops off.

What is it like riding a bike using echolocation?

It's thrilling but requires very focused and sustained concentration on the acoustics of the environment. I click as much as twice per second, way more than I usually do.

Is it dangerous to explore the world this way?

Much of the world lives in fear of threats to life and limb that are largely imagined. Despite my insatiable habit of climbing anything and everything, I never broke a bone as a kid.

How challenging is it to teach other blind people echolocation?

World Access has taught nearly a thousand blind students in over 30 countries. Many students are surprised how quickly results come. I believe echolocation capacity is latent within us—early man may have used it when artificial lighting was nonexistent. The neural hardware seems to be there; I've developed ways to activate it. Vision isn't in the eyes; it's in the mind. Our students say they've discovered a freedom they never imagined.



Watch Marco Grob's video interview with Daniel Kish on our digital editions.





Hay. Beautiful.

*Farmers in
Transylvania have
created a landscape of
flower-filled hay
meadows.
Can they endure?*



Every member of a Transylvanian family plays a part in the farming life. Eight-year-old Anuța, from Bogdan Vodă in the north, helps with the cows and sheep. The whole Borca family (right), from Breb, puts finishing touches on one of the 40 haystacks it makes each summer.





You can't help but smile as you walk in early summer through the grass-growing valleys of Transylvania. They ooze a kind of sweet-smelling well-being, largely because these valleys in the Carpathian Mountains in the center of Romania contain one of the great treasures of the cultivated world: some of the richest and most botanically diverse hay meadows in Europe.

You can find up to 50 different species of grass and flowers growing there in a single square yard of meadow, and even more within reach as you sit down among them. This flowery miracle is maintained not by nature but by nature worked with the human hand. The richness is there only because a meadow stays a meadow if it is mown every summer. Abandoned, it will be filled with scrub in three to five years. As it is, for the moment anyway, Transylvania is a world made beautiful by symbiosis. All day long the smell of the meadows gradually thickens, and as the sun drops, the honey-sharp smell of the butterfly orchids, night scented, pollinated by moths, comes seeping out of the hillsides.

Go for a walk, and you'll find the flowers crowding around your feet. Practically no chemical sprays and no artificial fertilizers—too expensive and distrusted by these poor, small-scale farmers—mean the hillsides are purple with meadow salvia and pink with sainfoin. Globe-flowers, a sort of enlarged buttercup, stand in the damper patches like Japanese lanterns. The little burnt-orange hawkweeds called fox and cubs are interspersed with the sorrel and the orchids,

the campanulas and the yellow rattle. Hares appear on the track in front of you. In places, the grasses have been roughly crushed and pushed aside—bears have been through here, looking for anthills to raid or fungi to plunder.

But if you go with Attila Sarig—a powerful and articulate 30-year-old farmer from Gyimes in Transylvania—the experience deepens. Sarig, sometimes with a murmured “Aha,” pauses now and then to pick the medicinal herbs that grow among the grasses: sorrel, snapdragon, gentian, marjoram, thyme, meadow salvia, all of which will hang and dry in his house or barn for winter infusions. “I know that I make this landscape by what I do,” he says.

The ethnoecologists Zsolt Molnár and Dániel Babai have found that among the people of Gyimes anyone over 20 years old can on average recognize and name more than 120 species of plants. Even young children know 45 to 50 percent of species. “It is because they still depend on biomass,” Molnár says. “They need to know what it is that is feeding them. Among the people I've surveyed, 72 percent of the visible flora and 84 percent of the botanical cover is



The Borca family relaxes after a working day that started early. Gheorghe (white shirt) and Anuța Borca (also in white) were married in July 1995, bang in the middle of the grass-cutting season. The honeymoon had to be shortened. “We started making hay again one week after the wedding,” Anuța says ruefully. This photograph was made in Maramureș, the Romanian-speaking part of northern Transylvania.



Sixty-three-year-old Mihai Țiplea has the help of his neighbors in Ferești to turn and dry the hay in his field. Work is shared, but each patch of meadow is individually owned and its boundaries carefully marked. Hayforks, made of hazelwood, the tines often polished by years of use, are handed down as heirlooms.



More sheep used to graze in the highest mountain pastures, but an increasing number of flocks now occupy fields near the villages. Some shepherds say that sheep in the lowland meadows are less beautiful, perhaps because there's less rain than in the surrounding highlands to wash them off.

known.” It’s a handmade world, largely unmechanized, too steep for reseeding, so people have come to know exactly what is there. Nowhere else, Molnár suggests, can people distinguish in their local vocabulary such a high number of separate habitats: shady, damp, steep, woody, mossy, and so on. “The average in the world is between 25 and 40,” he says. “The maximum anyone has found elsewhere is 100. Here in Gyimes it’s at least 148.”

THERE IS A POWERFUL CHAIN of connections at work here. In the summer the grass of the pastures feeds the one or two family cows. But in the six-month stretch from mid-November to mid-May, they must remain inside, where the hay provides their only sustenance. Only hay makes keeping cows a possibility, and only milk from cows makes human life viable here. People in Transylvania live on the nutrient transfer from meadow to plate. That is why, in these valleys, hay is the measure of all things.

When Réka Simó, Attila’s wife, who was brought up in Budapest in Hungary, first came to Gyimes, she could not believe how “people would only ever walk in single file through the meadows.” It was as if, she says, “the meadows were holy ground. As though these Transylvanians were living in a world dedicated to St. Grass.”

In a sense these Transylvanian farmers do live on the hay. Across the whole region, from Romanian-speaking Maramureş in the north to the ethnically Hungarian provinces in the center of the country and to villages occupied by German-speaking Saxons, the scale of their operations

is essentially medieval. Millions of people in Romania work on farms, with the smallest herds, the lowest yields, some of the highest levels of self-sufficiency, and among the lowest incomes in Europe. The average farm is eight acres. More than 60 percent of the milk produced in the country comes from farmers with two or three cows, almost none of it leaving the farm where it was produced. The mathematics is both simple and tyrannical. One cow eats four or more tons of hay in winter. That amount of hay needs up to five acres of ground to grow and might take ten hot, hard days just to mow. If you’re mowing alone and with a scythe, as still happens over large areas of the uplands, three cows mean a month of mowing.

But that is only the start of it. Each piece of grass must be handled ten or more times. First it is mown; then the mown stems must be raked into small heaps that don’t absorb the dew; then spread again in the next day’s sun to dry; then turned in the sunshine to dry the underlayers; gathered into a haystack in the field; eventually loaded onto a cart, a haystack on wheels, with the butterflies dancing up above the loaded hay; driven down the lanes to the homestead, where the horses are fed on the hay they have drawn there; unloaded at the barn into a deliciously rich-smelling heap like a dry, summer bouillabaisse; stacked high into the eaves of the barn—the chickens kicked out first so they aren’t smothered under the arriving hay—where it gathers as a rustling green fabric (“it must sound right; unless it sounds right, it won’t taste right”) in which the flowers retain their blues and yellows and reds; then, when the winter comes and the cows are brought in from the pastures, the hay for their daily bite must be cut from the dense body of the stack and finally fed to the animals beneath in their mangers.

In winter Adam Nicolson’s 16 beef cattle eat 90 tons of hay, made on his farm in the south of England. Photographer Rena Effendi grew up in the U.S.S.R. and has focused her work on the post-Soviet world.

species of plants. Even young children know 45 to 50 percent of species.

The milk of the cows in summer, when the grass in the pastures is rich, is made into soft cheeses, usually eaten at home or shared with the neighbors. Milk is also sold in the village or the nearby town. Or drunk at home. Young calves are given milk before being sold live or eaten, as the best possible meat. Very little butter is made nowadays. Instead, heart-threateningly delicious pig fat is eaten on bread. Occasionally, even the pigs are also fed on milk. By these various routes, the goodness of the grass makes its way into every corner of life.

BUT HAVE NO DOUBT: This is a world of no great riches. You can feel the hard work that keeps it going in the honed muscularity of every hand you shake, male or female. A farming family here can expect to live on around 4,000 euros (\$5,235) a year, often supplemented by income from another job. Less than half of the households have bathrooms. The price of horses is high because few people can afford a car. I've sat at a dinner table where the family have discussed

whether they should buy a horse or a tractor. The answer: a horse, because no one has yet invented a tractor that will give birth to another version of itself. On the other hand, you don't have to feed a tractor on the day it does no work.

During the communist years, from 1947 until 1989, the mowing regime on the high meadows was maintained. But after the revolution, which got rid of the Ceaușescus at the very end of 1989, the cooperative farms were dismantled, and lands returned to previous owners. People resumed the sort of small-scale farming they had practiced before communism, but from the mid-1990s it started to decline. Farmers got older. Young farmers thought they could make more out of arable farming or in city jobs. Milk could be bought cheaply from industrial-scale producers elsewhere. There was no sense then of the hay meadows being a rich, inherited asset.

As the old farmer Vilmos Szakács from Csíkborzsova says, in Western Europe “the general approach was to leave the old things behind.” Working abroad looked more tempting than



Transylvania is a plateau region surrounded by mountains. Traditional haymaking culture survives there not only because of remoteness and distance from markets but also because of the people's deep attachment to rural ways of life that have their origins in the Middle Ages.





Cousins Anuța and Magdalena Mesaroș, 17, are on their way to a wedding in Sat Șugatăț, Maramureș. Mothers and grandmothers like Maria Pop (above), from Cornești, spinning raw wool at home, devote hundreds of hours a year to making traditional embroidered clothes for their families.



Cooking up plum jam in the autumn is usually a man's job. It takes eight to ten hours of uninterrupted stirring to make sure the jam on the bottom of the pot doesn't burn. This grandfather from Sârbi wears the traditional small Maramureș hat. Anyone who sports one of these little hats in Bucharest will likely be laughed at.



Anuța Vișovan, 70, tends the fire at a still owned by her neighbor, in Breb, for making palinca, the plum, apple, or pear brandy whose name means simply “distilled spirit.” A fiercely delicious dram of it is given to every visitor. “When the first thing you do is have some palinca,” Lorinț Opreș, mill owner at Sârbi, says, “you know it’s going to be a good day.”

“The children come and look at the view and eat and drink

staying home with the cattle and the hay. Two months' work in Norway or Sweden on construction now earns a man enough to buy a house and some land in Transylvania. As in other Transylvanian communities, animal numbers in Csíkborzsova—a charming village in the east—crashed, from 3,000 cattle and 5,000 sheep in 1990 to 1,100 cattle and 3,500 sheep in 2012. Alternative employment meant fewer animals, fewer animals meant less hay needed, and less hay needed meant unmown meadows.

The forest started to creep back into them. As the shade of the trees closed over, the meadow flowers began to disappear. “We’ve seen the spruce trees coming up over the ridge to the south,” Rozália Ivácsony told me of her neighbor’s meadows west of Csíkborzsova. “The old man died, and the young one didn’t want it.” Of her own grown-up family, she says, “The children come and look at the view and eat and drink and go away. We’ve taught all of them not to become farmers. This land”—she waved her arm slowly around her own wonderfully beautiful mown hillsides—“is useless now. No foreigners want it, and it will be abandoned.”

Foreign money, earned by young men and women working abroad, began to flood into these villages. Houses that “in communist times cost six haystacks,” as the farmer Gheorghe Paul from Breb, in Maramureș, told me, “now wouldn’t cost less than 500 haystacks.” Old wooden dwellings have been demolished or renewed. In their place have emerged large houses with microwaves on melamine counters and eye-level grills looking out on farmyards where the old world persists: chickens and turkeys pecking under the plum trees; the cow waiting patiently in her low, lightless byre; the pigs snuffling in the sty; and the grandparents bringing in the hay from the meadows.

The problems were exacerbated by Romania joining the European Union in 2007. The clumsy definitions for European grant allocations prevented many small Transylvanian farms from getting European money. More than 70 percent of the intensely subdivided individual farms were too small for the Romanian bureaucrats in Bucharest even to consider them as farms. The EU says that nothing under three-quarters of an acre is an eligible plot, but most Transylvanian fields are smaller than that. Cow numbers have increased on some larger farms, but hygiene regulations designed for high-tech German and Scandinavian dairies cut into the viability of the old ways. Cottage cheese, for example, was always made in birch tubs. (“You must do everything gently,” Attila Sarig told me as he kneaded the curds, “like with a girl.”) The EU insisted that it be made on a stainless steel table. The traditional Transylvanian date on which to start mowing the low meadows in certain parts of Transylvania is St. John’s Day, June 24, but the Romanian government set the date at July 1. Additional European subsidies are available only if the meadow is mown on or after July 1, to allow flowers to seed and young birds to mature.

AS THEY SAW THEIR WORLD DRAINING away, people wanted to save it. “I want to hold on to the country my father and grandfather have made,” Józef Szócs says. And so, here and there, in small ways, they began to take control of their own lives. Local conservation organizations got to work. Milk had previously been bought from the villages by large dairy companies that ran the milk collection points and controlled the price. Starting in 2006, one or two communities, including Csíkborzsova, set up their own milk collection points, buying the storage and cooling equipment and establishing hygiene systems

and go away. We've taught all of them not to become farmers."



In her parents' house in Budești, Ileana Borodi, 24, minds her baby son, Ioan, nine months, while her daughter, Mărioara, three, occupies herself. Elderly family members often stay in older wooden houses, where walls are hand-painted with flowery designs. Younger people usually live nearby in modern homes built of brick and concrete, easier to heat and keep clean.



Clean, fresh river water surges into a traditional wooden washing machine in Sârbi, Maramureş, where after about ten minutes of pummeling, rugs are thought to be cleaner than by any other method. For about three dollars, you can rent time at the privately owned washing machine, never more popular than when getting household rugs ready for Christmas or Easter.



Corn has to be shelled before it is fed to the cattle. Ion Petric and his wife, Maria Vraja, who live in Breb, help out their neighbors' daughter, seven-year-old Adriana Țânțaș. Transylvanian family life and village life both remain intimately bound up with the needs and services of the farm animals.



Maria Covaci (above) kneels at her husband's coffin in the courtyard of their house in Strâmtura. Irina Veciunca (far right) is comforted at the burial of her husband, Ștefan, who died in June 2012. No funeral in Transylvania is complete without a warning from the priest of the dire fate that awaits those who have not led a good life.





The demand for hay is increasing, and meadows that would

that conformed to EU standards. Every farmer who brought his milk in pails and buckets to the collection point was paid—but only if his milk was clean and of good quality.

Results were immediate. The milk from those Csíkborzsova farmers who had joined the new system was collected and sold separately from other milk. The price of the clean milk rose at first by 50 percent and by 2012 was three times as high as for milk from other villages. At the milk collection point in Csíkdélne, I met Jenő Kajtár one evening. Still in his blue farm overalls, he had brought in the 50 liters (13 gallons) from the five cows he had milked. Things were going well. Previously he had four cows, now he had six, and in three years the price of milk had gone up fourfold, doubling when the new milk collection point had been installed, and again when the village cooperative had set up a direct sale point in Miercurea-Ciuc, the nearby town. Fresh, unpasteurized milk was now available at an automated milk machine, filled twice a day via a refrigerated delivery truck from the village. I asked Kajtár why he thought the city folk were buying his milk. “Because it is real whole milk,” he said, smiling under his mustache, “a piece of the past which their city life has left behind.”

I never thought the sight of a milk-dispensing machine would move me. But here was a symbol of people trying to keep something valuable in a world whose forces were doing their best to erode and destroy it. The milk machine in Miercurea-Ciuc might, amazingly, guarantee the continued life of those flowery meadows high in the mountains above us.

The economics remain fragile. The Swiss milk dispenser costs about \$13,000, and it earns about \$40,000 a year, but this kind of direct sale means that if one farmer puts bad milk into the system, those buying it fall ill, trust disappears, sales

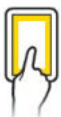
collapse, and the whole village suffers. The week I was in Csíkdélne, 4 out of 22 farmers had been banned for one week because they had submitted substandard milk. One or two had been banned permanently for chronic failure to meet the required standards.

Yet in a generally diminishing market, with the higher prices, cow numbers in the milk collection villages are going up. With increasing cow numbers, the demand for hay is increasing too, and meadows that would otherwise have returned to forest are being mown again.

And the people feel some deep pride in not abandoning the beauty they’ve inherited. “It is our land,” Anuța Borca, a young mother from Breb, insisted to me about her family meadows. “We have to take care of it. We have to teach the children the traditions. And teach them something that allows them to survive if they have no job.” She paused from the embroidery she was making on a linen shirt for her son. “It’s important because tradition is a treasure. If they learn it, they will be richer.”

I found another lady in Breb one day, Ileana Pop, embroidering a linen shirt for her son-in-law. Where, I asked, did the patterns come from? “Oh,” she said casually, “they come from the beginning of the world. But we mix old patterns with our own ideas. We never leave the style. We just play with the style.”

If only the economics could be sorted out, if only European agricultural subsidies were more attuned to local variation, if only the Romanian government were more alert to the astonishing landscape riches of Transylvania, then it might be possible to save this hay world. Transylvania is not yet a fossil. It is still alive—just—if in need of life support. But it represents one of the great questions for the future: Can the modern world sustain beauty it hasn’t created itself? □



On our digital editions watch a video of daily life among the Transylvanian haystacks.

otherwise have returned to forest are being mown again.



On the evening hillside outside Breb, alfalfa stacks stand sentinel. The roots of Transylvania go back at least a thousand years. The farming way of life will continue only if it is treasured and nurtured by the villagers and seen by Romania and the European Union as worth sustaining.



THE COMEBACK CROC

Once heavily hunted for its valuable skin but now protected, Brazil's yacare caiman is striding back in gratifying numbers.

Photographs by Luciano Candisani



After the caimans emerged at dusk, the photographer was reminded of an earlier encounter. At 15 he went with his dad to look for the crocs by flashlight: "The image of their eyes glowing like stars in a dark sky is something I will never forget."





IF YOU NOTICED THEM

at all, they'd look like nothing more than tiny, windblown seeds floating amid the rushes at the edge of a lagoon in Brazil's remote interior. Wait until dark, when the vast conspiratorial hush of the wetlands gives way to a chorus of chirpings and rustlings, and those little specks begin to slip away, vanishing in the murk.

These tiny dots are the watchful eyes of baby yacare caimans, members of the crocodylian family, barely two weeks old and scarcely longer than a pencil. By day they hide among aquatic grasses, concealed from herons or storks who might swoop in for a quick snack. By night they slip away to feast on insects and snails, graduating to bigger fare as they grow bigger themselves. Given time and opportunity, they can reach eight feet and be powerful enough to capture a capybara, one of the area's giant rodents. But that's all in the future. For now they are near the bottom of the pecking order, just trying to keep out of sight.

Hundreds, possibly thousands, of these hatchling caimans lurk in this one lagoon. And there are many more such lagoons in the Pantanal. This enormous flowering wetland along the Paraguay River in southwestern Brazil is not only home to what is probably Earth's largest crocodylian population but also the setting for one of conservation's great comeback stories.

Thirty years ago the yacare caiman appeared to be heading for oblivion, ruthlessly hunted to supply a lucrative market for crocodylian leather. Their numbers dropped alarmingly.

"Nobody can say for sure how many yacares were slaughtered, but it would have run well into the millions," says Cleber Alho, a conservation biologist with Brazil's University Anhanguera-Uniderp in Mato Grosso do Sul, who did much of his fieldwork in the Pantanal during the height of the poaching era in the 1980s.

Armed gangs would invade during the dry season and shoot masses of yacares congregated around shrinking water holes. "They skinned

Luciano Candisani photographed "Hippie Monkeys" for National Geographic Brazil. Roff Smith wrote about cheetahs in our November 2012 issue.





With the onset of the dry season, schools of fish abandon the Pantanal's shallow pools and swim toward deeper river waters—and often into the mouths of hungry caimans.

them on the spot and left the rest to the vultures,” Alho says. “I used to come upon piles of dead yacares rotting on the embankments. Fieldwork in those days wasn’t just depressing, it was dangerous as well, since the *coureiros*—the leather men—could be extremely aggressive.” A Brazilian government crackdown on poaching and a 1992 global ban on the trade of wild crocodilian skins eased the pressure on the beleaguered yacare population. The crocs themselves did the rest. After a string of intense rainy seasons—ideal for breeding—caiman numbers rebounded dramatically. As many as ten

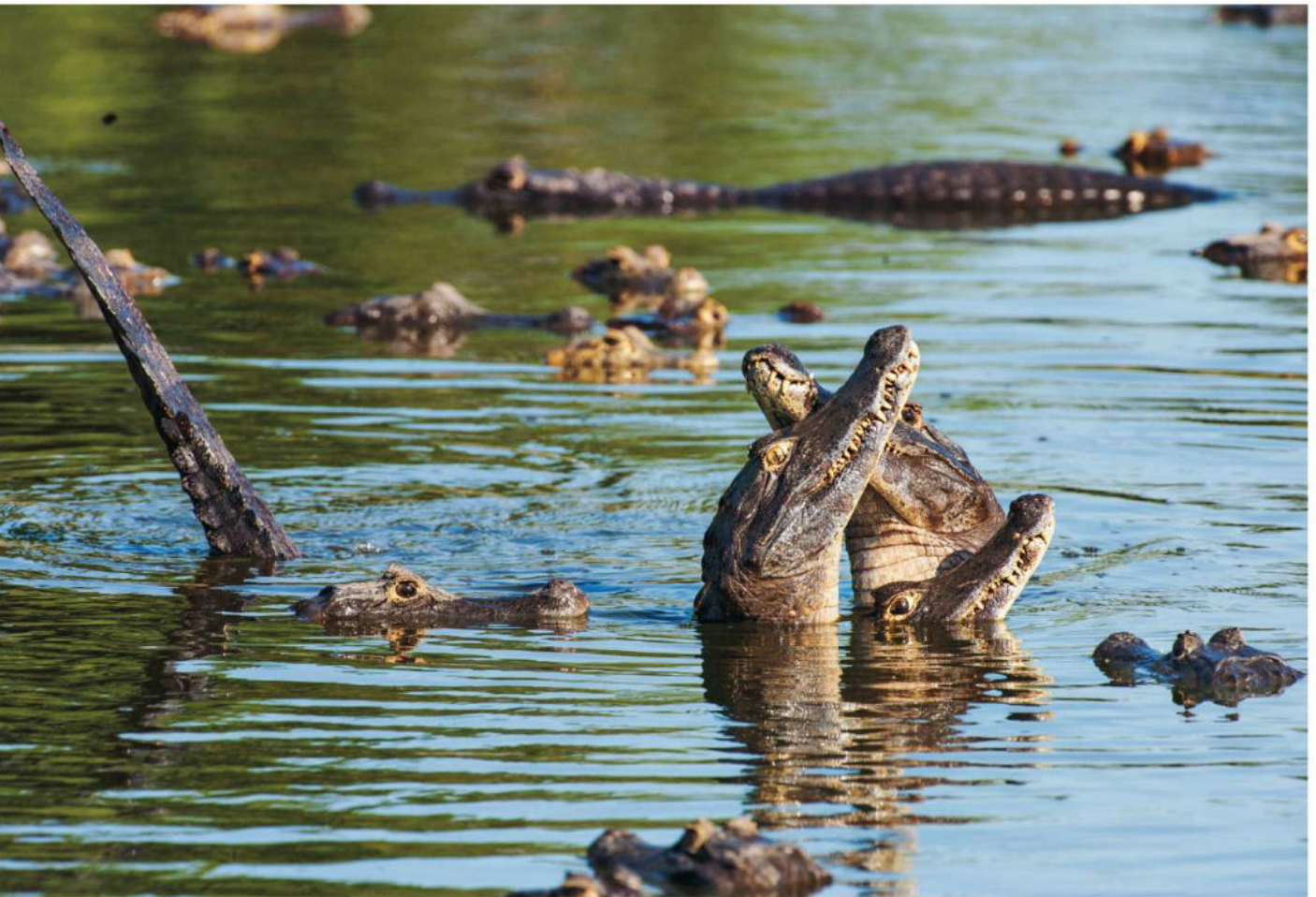
million yacare caimans are estimated to live in the wetlands today.

Even so, the yacare caiman is not yet out of the mire, warns Alho. “The thriving population in the Pantanal threatens to mask the problems the species is facing elsewhere in South America, where poaching continues and populations are vanishing.” Within the Pantanal itself, threats still loom: deforestation, dams, tourism, mining, seaport development. But for now at least, in the steamy aftermath of another bountiful wet season, the kings of the Pantanal seem secure on their throne. —*Roff Smith*



Barely eight inches long—a bite-size snack for any keen-eyed jabiru stork that happens along—these two-week-old caimans float among water grasses on hot afternoons. If trouble arises, they issue a distress call and nearby adults rush to their side.





Above: Male caimans dance and pirouette to establish dominance in an elaborate ritual that takes place in sweltering heat just before summer's heavy tropical rains. After the dance they head to the (hopefully) impressed females. Right: Perfectly camouflaged, a caiman lies on the forest floor.



NATIONAL GEOGRAPHIC ON TV



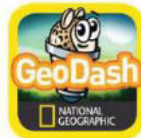
Monster Fish

It's a behemoth, that's for sure, but little else is known about the green sturgeon. Aquatic ecologist Zeb Hogan (left, in the Klamath River with a specimen) wants to learn more. Join him this month on Nat Geo WILD as he heads to the Pacific Northwest to study the elusive fish, which has been around since the days of the dinosaurs, can live to the age of 70, and can grow as long as seven feet.

EXHIBIT

A NEW AGE OF EXPLORATION This exhibit showcases National Geographic's storytellers and explorers through photos, video, and interactive displays. See photographers on assignment, scientists in the field, and explorers around the globe, from Mount Everest to the Mariana Trench. Open now at the National Geographic Museum. For tickets go to ngmuseum.org.

APP



WILD ANIMAL ADVENTURE Explore the African savanna and other habitats with Geo the robot. As you collect cards sporting pictures, trivia, and jokes, Geo will pick up skills, like the speed of a cheetah or the digging prowess of an armadillo. Free for iPad and iPhone; find it in the App Store.

TRIP

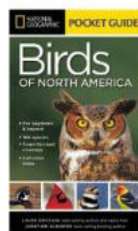
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MAP

STATE RECREATION ATLASES These atlases detail parks, campgrounds, trails, and more. Peruse the selection at natgeomaps.com.

Book of the Month



NG Pocket Guide to the Birds of North America

Laura Erickson and Jonathan Alderfer

Discover the joys of bird-watching with this concise volume written by two National Geographic experts. Full of essential information on 160 North American birds, it features colorful illustrations as well as tips for tracking and observing birds in the wild. Available now (\$12.95).

Adults 18 years and Older

Could Be Affected by a Class Action Settlement Involving Consumer Reporting

A Settlement has been reached in a class action lawsuit involving certain reports sold by LexisNexis. If you are 18 years or older, you are probably included in the Settlement because there is likely information about you in the LexisNexis databases.

What's this Case About?

The lawsuit claims that LexisNexis prepared and sold Accurint® searches and reports that were “consumer reports” under the Fair Credit Reporting Act (“FCRA”). The lawsuit claims that LexisNexis failed to follow certain FCRA requirements that apply only to “consumer reports.” LexisNexis disagrees that Accurint® reports are “consumer reports.” Both sides have agreed to the Settlement to resolve the case and provide benefits to consumers.

Who's Included?

If the databases used to prepare Accurint® brand products at any time between November 14, 2006 and April 19, 2013 contained information about you, you are in the Class. The databases contain names and addresses of all U.S. residents who have a credit history, as well as information from many public records such as telephone directories, voter registration records, motor vehicle registrations, and mortgage records.

What does the Settlement provide?

LexisNexis has agreed to design, implement, and maintain specific, substantial procedures that address the concerns raised in the lawsuit regarding the preparation and sale of Accurint® searches and reports to debt collectors. No money will be paid to Class Members.

Your Options

If the Court approves the proposed Settlement, then you will be bound by the Court's decisions – you cannot exclude yourself from the class. You will not be able to sue, or continue to sue, LexisNexis for the limited remedies being resolved by this Settlement. However, you will be able to file a lawsuit on your own to pursue any claims for actual money damages. If you do not like the proposed Settlement, you must object by **August 30, 2013**, as discussed further at CollectionReportLawsuit.com.

The Court will hold a hearing on **October 3, 2013** to consider any objections, whether to approve the Settlement, and to award attorneys' fees and expenses up to \$5.5 million. You can appear at the hearing, but you don't have to. You can hire your own attorney, at your own expense, to appear or speak for you at the hearing. You must let the Court know by **August 30, 2013**, if you intend to do so.

For more information: 1-888-538-5784 CollectionReportLawsuit.com



Caged Birds After 18 years covering conflict in Rwanda, Afghanistan, and Iraq, photojournalist David Guttenfelder was unsure if he had the skills for a delicate new assignment: documenting the trapping and eating of songbirds. But he soon found himself on familiar ground, enmeshed in a story with carnage and tension. He had an awakening as well. In Ayia Napa, Cyprus, he met a man who'd illegally caged a dozen wild birds. Guttenfelder thought: "This isn't how birds are supposed to be." In this case the authorities came in and freed the birds (below). —Daniel Stone



BEHIND THE LENS

Taking pictures of birds isn't your usual line of work.

DG: After so much time covering war, I remember some of my friends in Syria and Libya said to me, "You're out there covering birds?" I've spent a long time photographing people doing horrible things to each other, but seeing hundreds of birds suffering was a very challenging project. It made me realize there are other types of conflicts that need to be covered.

How did people justify killing them?

In Cyprus, when I listened to activists argue with local people, the Cypriots would say that the birds are delicious. One man told me, "Imagine the best thing your mother made for you as a

kid, then multiply it by a thousand. That's how delicious they are."

Did you eat any of the birds?

I did. As I learned from war photography, you sometimes need to hang around with people

who do things you don't agree with to photograph things you want to show. After spending an entire day with a family in Egypt that hunted songbirds, they invited me to eat with them. I probably ate three or four birds. It wasn't for me.

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Inner Space

An earthbound astronaut checks his controls in the cockpit of the Manned Aerospace Flight Simulator in Dallas, Texas, in the 1960s.

The indoor orbiter was suspended on a hydraulically powered gimbal to allow for a range of motion similar to that of a real spacecraft: “from full nose-up to full nose-down,” noted one paper on the vehicle. Surrounding the simulator was a spherical screen onto which images of the Earth or moon were projected. To further enhance the realism of the test pilot’s experience, speakers boomed the recorded roar of rocket engines, while vibrations buzzed up through the vehicle’s base and into the cockpit seat. —Margaret G. Zackowitz

👉 **Flashback Archive** Find all the photos at ngm.com.

PHOTO: NASA

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